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ORIGINAL ARTICLES.

I.—The Physiographic Significance of Laterite in Western Australia.

By W. G. Woolnough, D.Sc., F.G.S., Professor of Geology, University of Western Australia.

During the last six or seven years a series of valuable papers bearing on the origin of laterite has appeared in the Geological Magazine.[1] The conclusions arrived at have been somewhat diverse and contradictory. Dr. Fermor, on the one hand, regarded the laterites of India as residual in character, and believed that they represented the insoluble residues left in the process of rock weathering after the soluble constituents had been removed in solution. Mr. Simpson, at the other extreme, suggested that they represented the soluble material, leached out of the subjacent rocks during weathering under peculiar conditions, and deposited as a chemically-formed rock by precipitation at the surface of the earth.

Mr. Holmes and Professor Lacroix both appear to hold much the same view as that enunciated by Mr. Simpson. The fact that Dr. Fermor, in his admirable review of the work of Lacroix, does not dissent from the statements of the latter, suggests that Dr. Fermor and Mr. Simpson may really hold very similar views, and that the apparent differences may be, after all, due to method of expression and not to actual divergence of opinion.

It is quite possible that different methods of formation may occur under the widely different conditions of climate and geology exhibited by the various regions from which laterite has been described. Whether this is so or not, the author is wholly in agreement with Mr. Simpson in his explanation of the chemistry of laterite formation in Western Australia, but desires to go further and to extend and amplify the physiographic processes involved in the genesis of this peculiar rock.

A very brief summary of the physiography and geology of the south-western portion of Western Australia[2] will assist in the understanding of the problem. The most important feature of all is the Darling Range Escarpment. This extends as a straight line for at least 200 miles in a north and south direction from near Gingin

[1] Notably L. L. Fermor, "What is Laterite?": Geol. Mag., 1911, pp. 507–16, 559–66; E. S. Simpson, "Laterite in Western Australia": ibid., 1912, pp. 399–406; A. Holmes, "The Laterite Deposits of Mozambique": ibid., 1914, p. 529; L. L. Fermor, "The Laterites of French Guinea": ibid., 1915, pp. 28–37, 77–82, 123–9.

[2] For a more detailed account see J. T. Jutson, Bull. No. 61, Geol. Surv., Western Australia.

(30 miles N.N.E.)[1] to a point near Capel (110 miles S.S.W.). These points do not mark the limits of the feature in question, but beyond

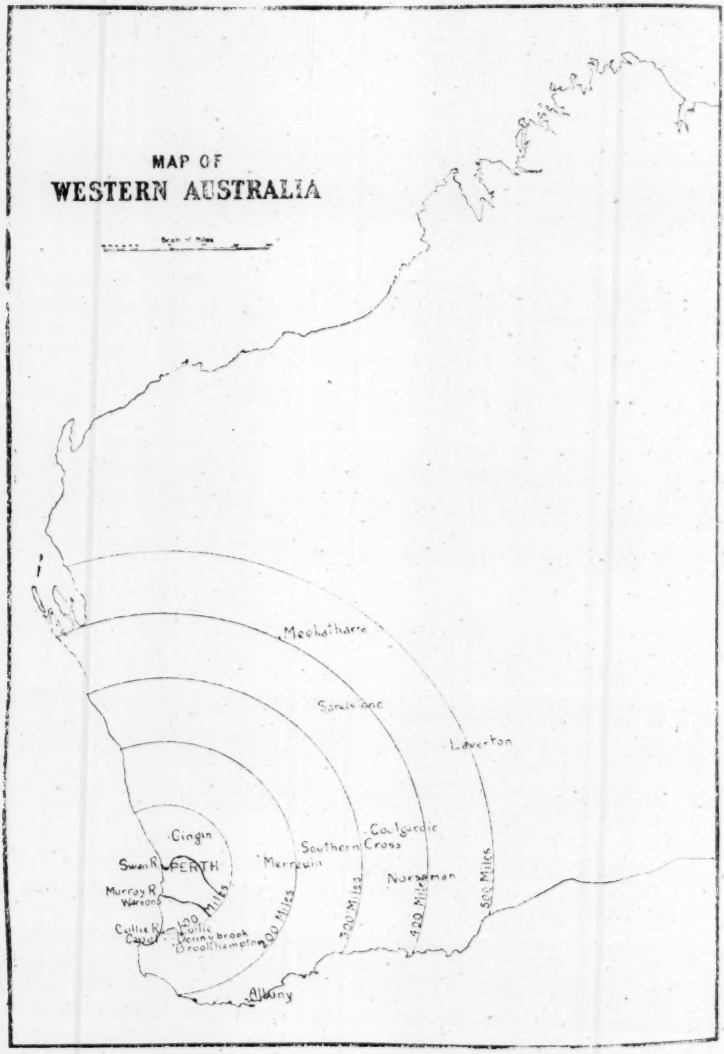

FIG. 1.—Map of Western Australia, showing positions of places mentioned in the text. In order to avoid confusion places in the immediate vicinity of Perth have not been inserted. Helena River is a tributary of Swan River. Brunswick and Preston Rivers are tributaries of Collie River.

[1] For simplicity in finding localities on the map the approximate direction and distance from Perth will be given in each case.

them the structure becomes complicated in marked contrast to its extreme simplicity within the specified zone. The escarpment has an extremely uniform altitude of about 900 feet above sea-level, and marks the boundary between the Coastal Plain on the west and the "Darling Range" on the east.

The Coastal Plain is very uniformly about 15 miles wide and consists almost exclusively of sandy deposits of recent age. In the neighbourhood of Perth these have been proved by artesian bores to extend to a depth of at least 2,000 feet below sea-level. The surface of the Coastal Plain is undulating, but does not, as a rule, rise to more than 150–200 feet above sea-level.

The name "Darling Range" is really a misnomer for the highlands to the east of the scarp. These highlands form actually one of the most perfect peneplains in the world, and they will be referred to, therefore, throughout this communication as the Darling Peneplain or Darling Plateau. The surface of this unit is gently undulating for the most part. Its average altitude increases gradually as we proceed east and north, so that it is 1,046 feet at Merredin (145 miles E.N.E.), 1,400 feet at Coolgardie (320 miles E.N.E.), 1,506 feet at Laverton (450 miles N.E.), 1,755 feet at Sandstone (330 miles N.N.E.), and 1,708 feet at Meekatharra (400 miles N.N.E.). The plateau is built up almost exclusively of extremely ancient crystalline rocks, some of which are of acid composition (granites and gneisses), others of which are basic (quartz-dolerites, epidiorites, "greenstones," etc.).

The escarpment is deeply trenched by streams which flow westwards into the Indian Ocean. The larger streams like the Swan, Helena, Murray, Brunswick, Collie, and Preston, have reached base level and have begun to widen their valleys just within the edge of the plateau. The smaller streams and all but very insignificant stretches of even the larger ones are, however, strikingly juvenile throughout their intra-plateau portions. The whole of the western part of the plateau is therefore intensely dissected and roughened by deep narrow gorges. This is an important point to remember in discussing the origin of the laterite. The zone of intense dissection is not very wide, and, from Chidlow's Well (20 miles E.N.E.), the levels on the Eastern Goldfields Railway (to Coolgardie, Kalgoorlie, and Laverton) indicate clearly the very slight relief of the area. Very rarely indeed do depressions fall more than about 200 feet below the average level of the surrounding country.

In the western zone of the plateau crystalline rocks in situ are met with only in the valleys of the young rivers which have dissected the surface. As soon as the peneplain level is reached the surface is covered with a dense shield of laterite. As Simpson has pointed out, the composition of the laterite varies sympathetically with that of the underlying bed-rock; where the latter is granitic the laterite is aluminous, where it is basic the laterite is ferruginous. In every case the laterite, which is usually solid for a thickness of from 3 to 6 feet, rests on a bed of kaolin. The basement is very well exposed in some of the railway cuttings, as, for instance, at Baker's Hill (30 miles E.N.E.), Hoddy's Well (50 miles E.N.E.), Gooseberry Hill (10 miles E.), and other places. The leaching of the rock has been so thorough

that the residual material is suitable for the manufacture of fire-bricks. These, and brick arches for locomotive fire-boxes, are made at Smith's Mill (15 miles E.N.E.) and at Clackline (50 miles E.N.E.). That the leached material is in situ is very clearly demonstrated by the preservation of minute aplite, pegmatite, and quartz veins through it (as at Hoddy's Well), and by the slight differences in colour and consistency of the kaolin caused by the presence of basic dykes through the granites. Some of these structures are only a fraction of an inch in thickness; yet, though they have been cracked into short sections, they preserve their continuity for considerable distances. This is clear proof of the residual character of the pipeclay foundation of the laterite, and indicates that the volume of the pipeclay is very little less than that of the rock from which it has been derived.

The laterite capping, as above noted, is usually from 3 to 6 feet thick. In many instances where it has not been stripped off (for railway ballast or road-making) the apparent thickness is greater because of the collapse of the capping through erosion of the pipeclay substratum at the edge of the outcrop. The laterite extends as larger and smaller continuous cappings over the plateau areas which have not yet come under the action of the dissecting streams. These cappings are thus the residual portions of a once continuous sheet which mantled the entire peneplain surface.

As we pass inland, beyond the area which is in process of active dissection by coastal streams, into the broad extent of undulating country forming the wheat belt of Western Australia, the distribution of crystalline rock and laterite becomes different from that near the western scarp of the plateau. The characteristic elements of the land surface are broad, exceedingly mature, meridional valleys alternating with low ridges. The valleys are heavily aggraded, and the slopes are well mantled with soil, though extensive outcrops of granites and greenstones are also met with at intervals. The ridges are partly of the same character as the slopes, that is, soil-covered, but are rather more than half composed either of "Sand Plain" or of large granite outcrops. The latter (the granites) form immense flat domes, sometimes several miles in circumference, and have played a very important part in the exploration and prospecting of the country. On their surfaces are found the "rock-holes" and "gnamma-holes" whence the earlier travellers obtained their water supplies. The "Sand Plains" are extensive areas of light, friable sandy soil, beneath which, at all events in many instances, occurs a bed of sandy lateritic material. The perfect pisolitic structure of the escarpment laterites is almost completely wanting in those of the sand plain, though well-defined concretionary structure is plainly discernible. Solid masses of concretionary laterite forming extensive cappings of the higher residuals are not encountered through the wheat belt.

Further east, again, the physiography alters once more. The meridional valleys are no longer definite stream channels, but have degenerated into strings of salt lakes, whose floors, consisting for the most part of comparatively insignificant thicknesses of detrital

material, are covered with crusts of salt and gypsum. The ridges are, to a large extent, very rocky, and are frequently, but not always, capped by lateritic material. This laterite is again very different in general aspect from that which mantles the western zone of the Darling Plateau. It is not decidedly pisolitic, but is rather cellular and cavernous in structure. Nevertheless, the effects of concretionary action are abundantly apparent throughout, and it shows every evidence of a mode of origin generally similar to that insisted on by Simpson. The author is by no means so familiar with these eastern areas, distant from Perth 200–400 miles, as he would like to be, but quite numerous traverses of the area have been made. In the western part of the Goldfields Belt, near Southern Cross (205 miles E.N.E.), for instance, the laterite in many cases, if not always, lies directly on the surface of the crystalline rocks and schists, without the intervention of any extensive layer of thoroughly leached pipeclay. The rock, however, is deeply weathered, and the lower parts of the laterite crust represent an impregnation of the very much rotted original rock.

Further east, again, for instance, at Coolgardie (220 miles E.N.E.), there is a partial return to the conditions of occurrence met with in the Darling Plateau. The "Red Hill" in this town is a very typical laterite-capped butte, strongly concretionary rock resting on a well-leached substratum, but one which is much more ferruginous than that which is characteristic in the extreme west. Throughout the Eastern Goldfields, so far as I have been able to observe, there is very little tendency to laterite formation on anything but the basic rock types. Granites, quartzites, or siliceous schists are entirely free from laterite coverings. In these eastern areas laterite cliffs often constitute what are known as "Breakaways", which form the shores of the salt lakes.

This brief and inadequate outline of the physiographic conditions under which the laterite is distributed in the south-western portion of Western Australia, indicates that the problem of its formation is more complicated than Simpson has shown. The author is wholly in accord with him with regard to the chemistry of the process of laterite formation, namely, by leaching of the soluble constituents of the subsoil, transportation of the materials in solution to the surface by capillarity, and precipitation of certain of the dissolved matters there, through alternate saturation and desiccation of the subsoil consequent on seasonal alternation of extremely wet with intensely dry seasons. Simpson, however, appears to believe that the laterite may have formed *on the surface of the Darling Peneplain*, and it is on this point that I disagree with him. The drainage of the area is far too perfect at the present day to admit of the upward leaching of solutions to any considerable extent. The rapid fall in the level of water in wells sunk through the laterite capping on the plateau, even at very considerable distances from the nearest deep valley, indicates the effectiveness of lateral drainage under existing conditions. In November and December, 1916, the author noted a fall in the level of one such well (at 50 miles on the Perth–Albany road) of upwards of 30 feet in six weeks.

The thesis I wish to establish is that the laterite was produced under *peneplain*, not *plateau*, conditions, that is, when the land surface stood at a very slight elevation above sea-level. Youthful streams cut down their valleys to base-level before they begin to widen them at all sensibly. Hence the development of maturity of river erosion, that is, the evolution of a peneplain, can be completed only at a slight altitude above base-level, which in this case was undoubtedly sea-level.

With a very gentle gradient mechanical transportation of sediment would be insignificant, and even in solution the lateral movement of material would be extremely slow. Chemical weathering, however, would be strongly favoured, and, given alternations of wet and dry seasons, the conditions for laterite formation, postulated by Simpson, would be ideally fulfilled.

If this view is correct it follows that the importance of laterite, from an historic point of view, is greatly enhanced. It owes its present position on the summit of the plateau to the uplift of the peneplain, the criteria for such an elevation along the Darling Escarpment, with down faulting of the coastal strip towards the Indian Ocean being complete in every particular. Hence it follows that the laterite capping serves as a stratigraphic horizon of no mean value. If we find areas of laterite markedly elevated above, or depressed below the general laterite level, we have a prima facie reason to suspect earth movement as a cause. In applying this principle, however, it is important to remember that the peneplain was never a perfect plane, but was always an undulating surface. Under these circumstances certain initial differences of level of the laterite capping must be postulated. In the Darling Plateau area it seems probable that these differences of level were of the order of 200 feet.[1]

Another possible source of error is the fact, mentioned by Simpson, that considerable areas of redistributed laterite occur. When due allowance has been made for these possible sources of error, a sufficient number of outstanding cases has come under notice to indicate that the importance of the general principle has not been overrated, and that *extraordinary differences of laterite level in adjacent areas indicate block faulting*. In most instances other criteria of faulting may be discovered which convert probability into certainty. As examples may be cited the occurrence along the foot of the Darling Range Scarp, in the immediate neighbourhood of Perth, of isolated remnants of a laterite-covered shelf or step. At Greenmount and Ridge Hill (10 miles E.), where two railway lines enter the scarp, this shoulder of laterite is prominent, while it can be detected at least three points immediately to the south of those mentioned. At Armadale (15 miles S.E.) and Waroona (60 miles S.) similar areas of low-level laterite occur. From these occurrences I believe we may suspect that the faulting of the Darling Range Scarp is of the nature of a step fault and not simply a single fault (see Fig. 2).

[1] The difference in altitude of Chidlow's Well (30 miles E.N.E.) and Wooroloo (37 miles E.N.E.) on the eastern railway, both on the laterite "level", amounts to 256 feet.

In this case the collateral evidence is not so strong as it is in some others. The Collie Coalfield (100 miles S.S.E.) is a Senkungsfeld in which a wedge of Permo-Carboniferous Coal-measures has been let down into a trough amongst the granites. This faulting was no doubt pretty ancient, but the movement has evidently been rejuvenated in very recent geological time. Here we have a difference of level of the solid laterites of 213 feet between Yokain and Penrith on the railway line immediately west of Collie. This difference is not enough *per se* to establish the faulting, but other criteria, both geological and physiographic, taken in conjunction with the laterite

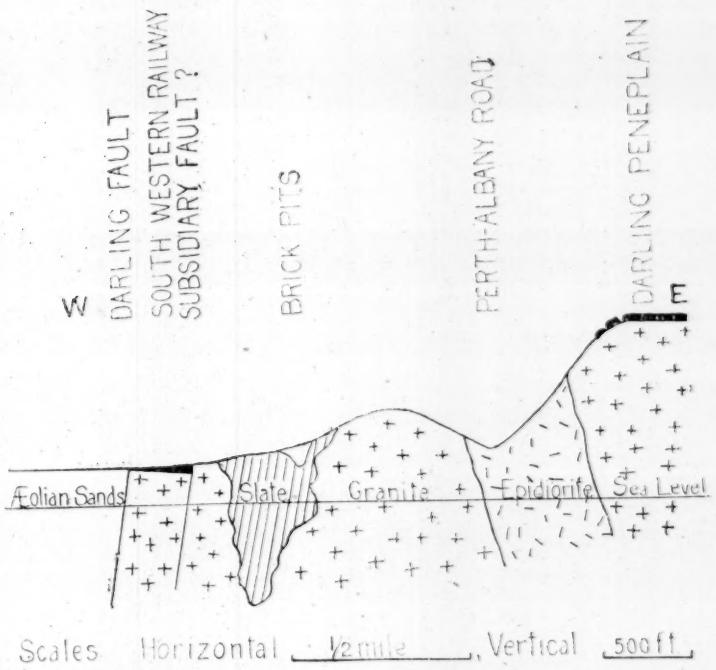

FIG. 2.—Sketch-section of the Darling Range Escarpment at Armadale, Western Australia (slightly generalized), showing relation of high-level and low-level laterites to possible slip-faultings. Laterite is shown black, and its thickness is exaggerated.

evidence, are amply satisfactory. Again, at Brookhampton (115 miles S.), a sudden jump of 200 feet in the laterite level was what first attracted the author's attention to a very decided recent fault there.

Within the wheat belt and the Eastern Goldfields no test as to the applicability of the theory has been made. In the Eastern Goldfields Maclaren believes that the laterite is still growing. While this may be so at isolated and favourably situated points it is quite possible that the statement cannot be substantiated generally. In the south-west it is found that many of the coastal streams have heavy cappings

of laterite on their alluvial terraces in the neighbourhood of the highlands. This is markedly the case, for instance, with the Preston River at Donnybrook (210 miles S.). It is quite possible that laterite may be actually forming at this and similar points, and the formation may be explained as follows:—

Most of the streams in question are fed by the subsoil drainage which flows beneath the laterite capping of the plateau. Their waters are, even in the wet season, hard and somewhat mineralized. As the dry season advances they all, with few exceptions, become unpleasant for drinking purposes. Many of them deposit iron abundantly, and give rise to iridescent films of iron oxide on the surfaces of pools. These films have been mistaken repeatedly for indications of petroleum. When the active flow of the streams ceases early in the summer, capillary action through the porous alluvium of the terraces may induce the upward concentration of the dissolved salts and give rise to normal laterite. It is to be noted that some of these river-terrace laterites are much more like the ordinary plateau laterite than are the detrital laterites. For this reason it may be advantageous to recognize a third river-terrace type of laterite in addition to the two varieties (solid high-level type and secondary detrital type) defined by Simpson. This mode of occurrence, if it is correctly understood by the author, may possibly explain the very common occurrence of laterite in the breakaways on the shores of salt lakes in the Eastern Goldfields.

The author doubts whether the occasional torrential rains of the arid areas are competent to produce laterite as supposed by Simpson. The latter authority (loc. cit., p. 401) mentions falls of 3·30 inches of rain at Mulline in one day and of nearly 4 inches at Coolgardie in two days. It is the universal experience that such torrential downpours cause comparatively little saturation of the soil. Even in very porous sandy areas the proportion run off to soakage is very high, and it is extremely doubtful whether the cycle of events necessary for laterite formation could follow such sudden downpours as those mentioned. Matters are quite otherwise when the rainfall is *seasonal* in character, as is very typically the case in the areas nearer the coast.

To explain the heavier laterization of the goldfields than of the wheat belt I would suggest that the question must be referred back to the previous geographic cycle. It has been shown that there has been a net uplift of the Darling Peneplain of nearly 1,000 feet on the west, and probably of considerably more on its eastern side. If the theory of laterite formation under low altitude conditions is correct it follows that the goldfields laterite must have been formed when the land stood much lower than it does now.

The presence of marine fossils at peneplain level at Norseman (350 miles E.S.E.) indicates that, at no very distant epoch, the sea extended much further inland than the present head of the Great Australian Bight. It is well known that in comparatively recent geological time the climate of Central Australia was much moister than it is at present, and it is reasonable to suppose that a much increased humidity was experienced in the Goldfields area. Under these circumstances it is very easy to account for the extensive

laterite formations of the region. The wheat belt was probably sufficiently distant both from the known coastline on the west and from the problematical coastline on the east to experience so light a rainfall as to preclude extensive laterite formation of the normal type.

Before leaving the subject of origin of laterite it may be of interest to point out that somewhat similar formations abound in Australia under conditions pointing very conclusively to conditions of formation identical with those laid down by Simpson for the Western Australian laterite.

In South Australia, where eruptive rocks are comparatively rare, and where marine sediments and schists predominate, the place of laterite is taken by almost ubiquitous "travertine", an impure limestone with highly perfect concretionary and pisolitic structures encountered under conditions quite similar to those of the western laterite.

Throughout the area occupied by the highly siliceous Upper Cretaceous Desert Sandstone formation in Central Australia, very widespread concentration of silica has followed a course identical with the concentration of lateritic materials. The result has been extensive opalization of the sandstone and the formation of porcellanites and quartzites.

Particularly in the wheat belt and goldfields of Western Australia it is usual to find granite outcrops "case-hardened" to a depth varying from a few inches to several feet. This phenomenon is evidently due to a superficial concentration of materials derived from the somewhat soft and crumbly internal portion of the rock, and it is to be explained in the same way as the production of laterite. This "case-hardening" of granite outcrops is an important factor in the production of the "gnamma-holes" or natural tanks in which so much of the scanty water supply of the arid interior is conserved.

Summary.

The author is of opinion that—

1. Laterite in Western Australia is formed by the leaching of subsoil salts during seasons of heavy rainfall, and capillary attraction of the solution to the earth's surface during intervening dry periods; the dissolved matter being deposited in a concretionary fashion in the surface layers of the soil.

2. Laterization can occur only in areas where drainage is almost at a standstill. This usually involves the existence of a peneplain almost at sea-level.

3. High-level laterite is a criterion of elevation of the land.

4. Difference in laterite level suggests faulting, which can often be proved by collateral evidence.

5. Outstanding differences of opinion with regard to broad features in the physiography of Western Australia may be reconciled by recognition of the essentially low-level nature of laterite.

II.—Pleistocene Glaciation of New Zealand.

By Prof. James Park, F.G.S., University of Otago, Dunedin, New Zealand.

(PLATE XIV.)

In the June issue of the Geological Magazine[1] for 1917 there appears an article by Mr. C. T. Trechmann, D.Sc., F.G.S., on "The Glaciation Controversy in New Zealand", in which he traverses my views as to the extent of the Pleistocene glaciation of this Dominion. I regret that my recent journeys to the Isle of Pines and Cape Yorke Peninsula and the irregularity of the oversea mails arising from the war conditions have prevented an earlier reply. Mr. Trechmann deals first with the glaciation of the North Island. He says it seems to him that the question of the glaciation of the North Island stands or falls with the origin of the striations on the large andesitic boulder lying near Mangaweka in the Rangitikei Valley (see Plate XIV). He selects these striations as the sole criterion of former glaciation, and argues that "if the scratches are not glacial the boulder is not glacial, and if this boulder is not glacial none of the others are glacial, and the chief evidence for a glaciation of the North Island fails". As a matter of fact this great striated boulder was not discovered by me till 1915,[2] or some five years after the close of the glaciation controversy between Dr. P. Marshall and myself.[3] Its existence was unknown in 1909. At that time I relied on other evidences of glaciation that Mr. Trechmann passes over with little or no comment.

I will briefly summarize the other evidences. In 1909[4] I discovered at Turangarere, in the Hautapu Valley, a great tumbled pile of angular and semi-angular boulders of andesite that range in size from 1 to 6 feet in diameter; still greater piles and larger masses at Mataroa and Taihape, and a smaller pile at Utiku. These boulders are foreign to the Hautapu basin, which is composed of Pliocene marine clays that are interbedded with a few thin beds of shelly limestone. The only possible source of these andesitic masses is the great volcano Ruapehu (9,000 feet), which is separated from the Hautapu Valley by the Wangaehu Valley and the Waiouru plateau-like ridge that forms the divide between the Wangaehu and the Hautapu Rivers.

The present distribution of the andesitic piles would tend to show that, when originally deposited, they extended across the Hautapu Valley, and formed barriers that have since been breached by the Hautapu River. The smaller material was resorted during the process of excavation, and spread out as gravelly deposits along the present course of the river.

In 1909 I postulated that the agent which transported the andesitic material across the Wangaehu Valley and the Waiouru divide, and deposited it in widely separated piles in the Hautapu Valley at distances ranging from 20 to 40 miles from its source, was a Pleistocene extension of the existing Ruapehu glacier.

[1] Geol. Mag., Vol. IV, pp. 241–5, 1917.
[2] Trans. N.Z. Inst., N.S., vol. xlviii, pp. 135–7, 1915.
[3] Trans. N.Z. Inst., vol. xlii, pp. 589–612, 1909.
[4] Trans. N.Z. Inst., vol. xl, pp. 575–80, 1909.

In 1915,[1] near Mangaweka, on the west side of the Rangitikei River, a few miles below the junction of the Hautapu, and nine miles farther down than the lowest previously known pile of andesitic blocks, I discovered the solitary conspicuously striated andesitic boulder to which Mr. Trechmann refers. This block lies on the Rangitikei terrace at the foot of a ridge of Pliocene marine clays, 1,070 feet above sea-level. It measures about $14 \times 6 \times 5\frac{5}{6}$ feet, and weighs over 37 tons. The underside and one end for a height of two feet are smoothed, rounded, and scored with innumerable fine striæ and hundreds of deep grooves, most of which run parallel with the longer axis of the block (see Pl. XIV, Fig. 2). The smoothed and striated surface has an area of some 90 square feet.

Mr. Trechmann always refers to the markings as "scratches". He makes no reference to the deeper grooves which occur so plentifully. By this omission and the constant reference to scratches, he unconsciously conveys an erroneous impression as to the extent and nature of the markings. And this minatory impression is not diminished when he states that the surface of the boulder is much decomposed and weathered. As a matter of fact all andesites are prone to weather rapidly; and if the striæ and grooves are Pleistocene, as I contend, the wonder is that weathering has permitted any trace of the striæ to remain. In my opinion, the preservation of the markings is due to the protection afforded by the clays and soil on which the boulder rested, and in which the underside is still partially embedded.

Mr. Trechmann says that the decomposed surface can almost be scratched with the finger-nail, and that scratches can easily be made on it with a knife blade. The "scratches" could, in his belief, easily have been made by the boulder moving downhill over gravelly soil or over other stones. According to this view the decomposition of the surface had already taken place before the boulder began its downhill movement. As this seems to be the essence of his contention, I have again examined the boulder and find that in all the deeper grooves the skin of decomposed rock conforms to the contour of the groove. Clearly the weathering took place after the grooves were formed, and not before, as Mr. Trechmann's suggestion would seem to imply.

The smoothing, scoring, and grooving of a rock mass by its downward movement under the influence of gravity is perhaps not accomplished with the ease assumed by Mr. Trechmann. There is no evidence that the Mangaweka erratic does not now lie in the place where it was left by the agent which carried it from Ruapehu. The old flood-plain of the Rangitikei is about 250 feet above the river terrace on which the boulder lies. Even if we assume that the boulder did at one time lie on the surface of that old plain it will, I think, be difficult to prove that its downhill movement could produce the smoothing and grooving we now see on the under surface of the block. It seems to me that when the excavation of the old flood-plain reached the boulder one of two things would

[1] J. Park, Trans. N.Z. Inst., vol. xlviii, p. 136.

happen. Either the boulder would incontinently tumble down to the present level, or it would slide down if the slope of the terrace face exceeded the angle of rest. When a heavy body descends on a gravel face, the material in contact with the body moves downhill at the same time, and this flowage would not, in my belief, lend itself to the smoothing and grooving of the heavy body.

The large size of this solitary erratic, its transportation across the Waiouru divide, its great distance from its source, its grooved and striated underside, and the existence of a considerable glacier on Mount Ruapehu, the place from which it originally came, have led me to the conclusion that it was carried to its present site by a Pleistocene extension of the Ruapehu Glacier that flowed down the Hautapu into the Rangitikei Valley.

Further, I know of no agent but a glacier that could transport and pile up the tumbled masses of andesitic rock that occur at widely separated points of the Hautapu Valley.

Turning to the South Island Mr. Trechmann deals mainly with the Taieri or Henley deposit. He says that in his opinion this drift is not glacial, and concludes that the glaciation was alpine and not of a regional type. This great deposit has been shown by the careful mapping of Mr. A. G. Macdonald, B.E., to extend from Saddle Hill, near Dunedin, to the Clutha Valley, a distance of some 32 miles. It occurs as a sheet on the west side of the coastal range that separates the Taieri Valley from the sea. It rises from sea-level to a height of 1,000 feet, and in many places forms conspicuous cliffs near the summit of the range. A distinctive feature is its proneness to form great landslides. Its thickness in the Taieri Gorge has been estimated at 1,500 feet, but this is probably an underestimate. The dip is to the westward at low angles. The lower portion is composed of rudely bedded angular fragments of mica-schist and an occasional large angular block of the same rock. The upper portion of the deposit shows little sign of bedding, and generally the material is coarser and large angular blocks more plentiful than in the lower portion.

As Mr. Macdonald's maps[1] clearly show, this deposit near Dunedin rests on the Oamaruian (Miocene) Coal-measures, at the Taieri Gorge on Palæozoic mica-schist, at Milton on the Oamaruian Coal-measures, and further south on Kaitangatan (post-Senonian, probably Danian) Coal-measures. Although mainly composed of mica-schist blocks, slabs of limonitic conglomerate from the Oamaruian series are not uncommon in the deposit on the range near Milton. The Taieri deposit was always considered by Mr. J. T. Thomson and Captain Hutton to be a glacial moraine, and Mr. McKay reported that it looked like a glacial deposit. I have described it as fluvio-glacial, and on no occasion during the glacial discussion in 1909 did Dr. Marshall challenge its glacial origin.

Mr. Trechmann states that he was struck with the dissimilarity of this deposit to any glacial moraine that he had ever seen. To this I would say that the rudely stratified fluvio-glacial drifts in the

[1] These manuscript maps are filed in Otago University. They were prepared in connexion with a research scholarship held by Macdonald.

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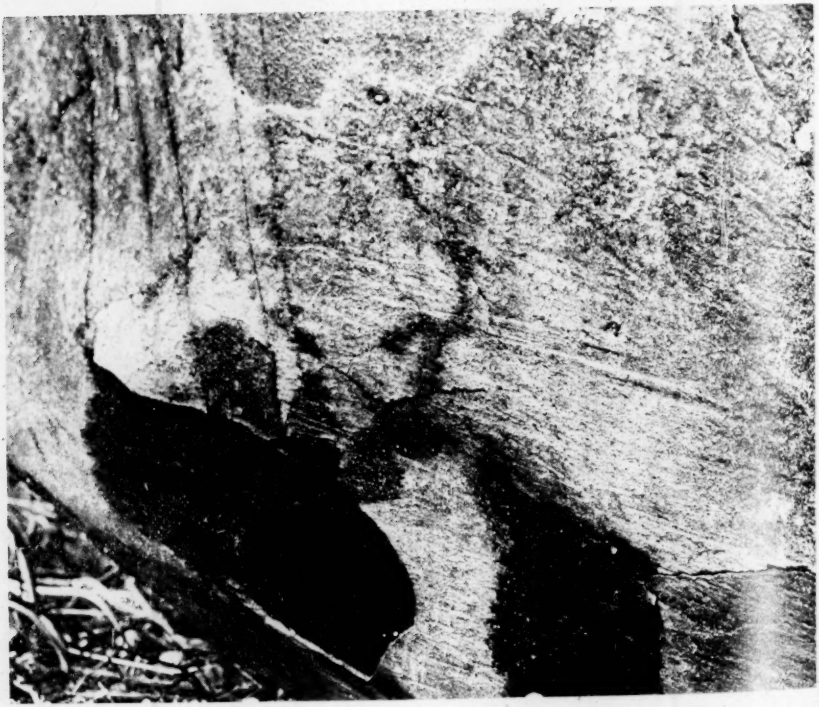


FIG. 1.—Great erratic of Andesite near Maungaweka, North Island, New Zealand.
,, 2.—A portion of surface showing grooves and striæ.

Cromwell and Manuherekia basins in Central Otago and the outwash drifts at the end of the Tasman glacier present many features in common with the Taieri Moraine.

He refers to the fault dislocations of the Blue Spur deposits; and expresses the opinion that they appear to be much earlier than the Pleistocene, but he gives no data in support of this view.

Mr. Trechmann says there is no evidence of transported erratics at the foot of the Otago Peninsula and Banks' Peninsula. At the former I know of no erratics, but there are deposits near Dunedin that if not glacial are otherwise difficult to explain. I have never contended that an ice-sheet extended to the foot of Banks' Peninsula, or even covered any portion of the Canterbury Plains. What I have postulated was that glaciers descended to the existing sea-strands where these strands coincided with the Pleistocene strands, as on the east coast of South Otago and in South Westland. The Pleistocene strand of South Canterbury followed the foot-hills that form the western boundary of the plains. At the maximum Pleistocene extension the Canterbury Plains were only in the early stage of formation. Perhaps the fault that I have been misquoted on this question lies at my own door. When discussing the Pleistocene extension of our glaciers I thought it would be self-evident that this glaciation could only refer to New Zealand as it existed in the Pleistocene.

Reference is made by Mr. Trechmann to the freshness of the glacial phenomena in the Alpine regions of New Zealand. The glaciation there is that of to-day or yesterday. In my belief it would be surprising to find the same freshness among the glacial phenomena developed during the Pleistocene extension of the glaciers.

In conclusion, let me say that Mr. Trechmann was a most welcome visitor to the shores of New Zealand. His palæontological researches have thrown valuable light on some problems that long baffled New Zealand geologists; and for this reason I regret that I am unable to see eye to eye with him on the glaciation question.

EXPLANATION OF PLATE XIV.

Fig. 1.—Reproduction from a photograph of large Andesitic Boulder near Mangaweka in the Rangitikei Valley, New Zealand. Measures 14 × 6 × 5·5 feet; weight over 37 tons.

Fig. 2.—Portion of the surface of the same Boulder, showing grooves and striations. Reproduced by permission of the New Zealand Institute from the Trans. N.Z. Inst., vol. xlviii (N.S.), pp. 135–7, 1915.

III.—The Recent Geological History of the Baltic and Scandinavia and its importance in the Post-Tertiary History of Western Europe.

By Sir Henry H. Howorth, K.C.I.E., F.R.S., F.S.A., F.G.S.

(*Continued from the August Number, p. 367.*)

WE will now try and picture to ourselves how the circulation of the water was affected by the breach in the land bridge. We have seen in the earlier part of these papers that one of its effects

was that the southern and western part of the Baltic became rapidly richer in marine forms. This is because the Straits between Gjedserodde in the island of Falster and Darrserort on the mainland of Mecklenburg form a great barrier to the eastern migration of the marine mollusca, whose species increase greatly in numbers when we pass westward of them. This seems to again point to the fact that the inflow of salt waters into the Baltic from the North Sea passes chiefly through the deeper Belts and not through the shallower Sound, which is the chief outlet of the more brackish Baltic water. On the other hand, the Swedish side of the sea remains poor in fauna until we reach the latitude of the island of Saltholm, due partly to its greater shallowness, which only allows a smaller proportion of the incoming North Sea water to pass. Mr. Dickson, who has written a great deal on the coasts and currents of the latter sea, argues that the rotation of the earth causes the outgoing water of the Baltic to cling to the Swedish side. It is, at all events, plain that the part of the Sound south of Saltholm is in its marine life to all intents and purposes a part of the Baltic. North of Saltholm, as Oersted has shown, the marine life becomes much richer. The wealth of life, however, is limited to the deep water in the middle of the Sound, while the shallower water forming the littoral zone continues to be very poor on both sides as far as the exit of the Sound into the Cattegat. It seems plain that since the great submergence there has been a certain slight uplift of the land along the south coast of Skåne and on both sides of the Sound; here again it is marked by a very poor and littoral fauna which has crept into the waterway from the Baltic. These later littoral beds lie on portions of sunken turf and other subaerial deposits.

Let us now pass northwards into the Cattegat and compare the marine life of this Gulf with that of the Baltic. The contrast is graphically given in the following table which I take from Professor Brandt's memoir "Die Fauna der Ostsee" (Verhand. Deutsch. Zool. Gesell., 1879, p. 10, etc.).

	Cattegat.	Kiel Gulf.	Central and Eastern Baltic.	Gulf of Bothnia.
Fishes	—	75	40	23
Ascidia	20	5	—	—
Mollusca	88	23	6	4
Prosobranchia	85	17	3	1
Opisthobranchia	—	23	2	—
Decapoda	55	9	2	(1)
Amphipoda	113	18	11	5
Isopoda	41	7	7	3
Cirripedia	—	3	1	1
Chætopoda	133	43	9	1
Bryozoa	65	17	1	1
Echinodermata	36	6	(2)	—
Actinozoa	16	4	—	—
Acalepha	—	2	2	—
Hydrozoa	48	15	1	1
Spongia	26	13	—	—

We will now turn to the more detailed features of the Cattegat. It is divided very distinctly into two sections marked by their respective contents. The line between the two runs through the

island of Laesö, which, as I showed in a former paper, is surrounded by a shallow sea bottom and is covered with the debris of a littoral fauna; and which it is generally thought was at a not distant date joined to the mainland of Jutland. At all events it is plain that we have in this southern section of the Cattegat a very distinct marine sub-province which ought to be united, not with the northern section, but with the Sound, and is marked notably by the presence of a considerable number of shells which are absent in the northern section.

The following shells are absentees there:—

GASTEROPODA.

1. *Aclis ascarus.*
   Petersen, however, thinks the dead shells so named found by Collin at Hellebaek may be *Aclis supranitida*, which occurs in both lists, see pp. 71 and 80.
2. *Parthenia spiralis.*
   Also found in the Limfiord, ib., 75.
3. *P. interstincta.*
   Also found in the Limfiord, ib.
4. *Odostomia acuta.*
   Subfossil in the Virk Sound.
5. *O. unidentata.*
   Also fossil in the Limfiord.
6. *Triforis perversa.*
   S.E. and S.W. of Laesö.
7. *Natica islandica.*
8. *Velutina lævigata.*
9. *Trophon truncatus.*
10. *Fusus (Neptunea) antiquus.*
11. *Scutellina fulva, vulgar.*
    Cattegat.
12. *Chiton albus.*
    Apparently only in the S. of Cattegat Sound.

LAMELLIBRANCHIA.

1. *Mytilus phaseolinus.*
   A new shell in S. of the Cattegat only, and not found N. of Laesö.
2. *Cardium fasciatum.*
   Not found N. of Laesö.
3. *Astarte borealis.*
   In the W. Baltic and S. Cattegat; dead specimens W. of Laesö.
4. *A. compressa* or *sulcata.*
5. *Cyprina islandica.*

The presence of those shells in the south, but not in the north, of the Cattegat I would explain as probably due to the erratic history of the great Danish gulf known as the Limfjord, which virtually separates Jutland from Wendsyssel and which discharges itself into the Southern Cattegat, of which it forms a kind of gulf.

Through the Limfjord the Cattegat has had an intermittent communication with the North Sea. Its eastern opening into the Cattegat has always been open, but its western one into the North Sea has at times been for a considerable period silted up and closed by a cul-de-sac, as I mentioned in a previous paper (GEOL. MAG., Dec. V. Vol. II, p. 11). The continual breaking down in the eighteenth and nineteenth centuries of the narrow isthmus separating the Limfjord from the North Sea occasionally flooded its western part with salt water from the latter sea, thus raising its salinity to 18 per thousand. This led to the importation there of a considerable number of North Sea fish and of certain molluscs like the oyster, *Tapes pullastra*, and the typical form of *Cardium exiguum*, which does not live in the eastern part of the fjord.

Morlot says the Canal of Agger by which the Limfjord entered the North Sea had become so narrow that only small vessels could pass, and it threatened to close altogether in 1859.

It is not impossible that a number of the shells occurring in the Southern Cattegat and not in the Northern may have entered it from

the North Sea by way of the Limfjord during one of the intervals when it was open at both ends. Others may have been brought in accidentally by ships or otherwise.

So much for the absentees from the northern section. On the other hand, the latter contains a considerable number of shells not in the southern part.

On comparing Petersen's lists of the shells from the two sections of the Cattegat I find the following absentees from the southern area:—

Gasteropoda.	Lamellibranchia.
1. *Scalaria tortosa.*	1. *Pecten maximus.*
2. *S. Trevellyana.*	2. *Mytilus Adriaticus.*
3. *S. lactea.*	3. *Modiolaria discors.*
4. *Volvula acuminata.*	4. *Nucula decussata.*
5. *Philine pruinosa.*	5. *Cardium Norwegicum.*
6. *Acera bullata.*	6. *C. nodosum.*
7. *Lacuna pallidula.*	7. *C. edule.*
8. *L. divaricata.*	8. *Lucinopsis undatum.*
9. *L. membranacea.*	9. *Isocardia cor.*
10. *L. inconspicua.*	10. *Venus fasciata.*
11. *L. parva.*	11. *Losinia exoleta.*
12. *Natica Montagui.*	12. *Tellina pusilla.*
13. *Capulus Hungaricus.*	13. *T. tenuis.*
14. *Fusus propinquus.*	14. *Solen ensis.*
15. *Mangelia costata.*	15. *Mactra stultorum.*
16. *M. nebula.*	16. *Thracia convexa.*
17. *Trochus milligranus.*	17. *Cochlodesma (Triforis?) perversa.*
18. *Nacella pellucida.*	18. *Lyonsia Norvegica.*
19. *Dentalium (Antalis) entale.*	19. *Neæra cuspidata.*
20. *Chiton ruber.*	

It is plain that while the southern section of the Cattegat ought zoologically to be joined with the Sound, the northern part ought to be united with the Skagerack and the Christiania Fjord.

The reasons for the disparity in the contents of the two sections of the Cattegat is probably the absence of the necessary quantity of salt in the waters of the southern section. It may be also due partly to the fact that the waters of the latter are not deep enough, the greater part of it being in fact much shallower than the northern part. Let us now return to the raised beaches of the Cattegat. In them there is a marked contrast between their contents and the living fauna of the great waterway.

I will now give a list of the shells which have occurred in the raised beaches and kitchen-middens. Those which are rare and only occur occasionally are marked with an asterisk.

Gasteropoda.	
**Odostomia* sp.	*Cerithium reticulatum.*
**Triforis perversa.*	**Utriculus truncatulus.*
Litorina rudis.	**Neritina fluviatilis.*
L. obtusata.	**Rissoa striata.*
L. litorea.	*R. membranacea.*
L. var. *tenebrosa.*	*Acera bullata.*
Hydrobia sp.	**Lamellibranchia.**
Lacuna inconspicua.	*Ostræa edulis.*
**L. divaricata.*	*Mytilus edulis.*
Nassa reticulata.	*Cardium exiguum.*

Cardium edule.	*Tellina (Macoma) Balthica.*
Cardium var.	**Corbula gibba.*
Tapes pullastra.	**Modiolaria discors.*
T. aureus.	*Montacuta bidentata.*
**T. decussatus.*	*Scrobicularia piperata.*

This list differs from that given by Petersen in excluding *Anomia squamula* and in retaining the name *Scrobicularia piperata* which he called *S. plana*. It is perfectly plain that it only represents a portion of the mollusca which were contained in the Southern Cattegat when the raised beaches were deposited. Here the beaches are all at a very low level; they form, in fact, the concluding factors of a series which occur at declining levels as we proceed southwards, but were doubtless deposited synchronously at different points on the coast from the Christiania Fjord to the Öresund, and represent only the littoral series. It is, in fact, interesting to compare a small section of the Gulf, namely, the Holbeck Fjord, where the following shells are now living which have not occurred in the raised beds.

Buccinum undatum.	*Mactra subtruncata.*
Tectura testudinalis.	*Thracia papyracea.*
Abra alba.	*Saxicava rugosa.*
A. nitida.	*Mya truncata.*
Solen pellucida.	*M. arenaria.*

What is much more important and interesting is the absence from the present waters of the Southern Cattegat of a number of shells with a wide distribution which abound in the raised beaches and also in the kitchen-middens of that channel. I have described at some length the remarkable consequences which have been deduced from this absence in previous papers (Geol. Mag., 1905, pp. 12–15, 557–9). The general conclusion of the arguments of Petersen and others is that the extermination or emigration of these molluscs was due to the Baltic breach which flooded the Cattegat with an excess of fresh water, and that this was coincident with the end of the kitchen-midden people. It enables us to roughly date that event at some eight or nine thousand years ago. The only fresh fact I need mention is the addition of *Pholas candidus* to the list of migrants. It is not now found nearer than the south of Norway.

By far the most interesting of these absentees are the oyster and the three species of *Tapes*. Petersen named the beds in which he found this series of shells *Tapes* beds, and he proceeded to argue that when they were deposited the waters of the Southern Cattegat were not only salter but probably also warmer than they are now, and approximated more to those of the Skagerack than the North Sea.

In regard to the connexion of the Baltic with the Cattegat, it is interesting that while the oyster has never occurred in the *Litorina* deposits in the Sound, it has occurred in the deposits of the Great Belt probably as far south as the Svendborg district (*Aarb. for Nord. Oldk. Hist.*, p. 321, Copenhagen, 1888), showing that before the Baltic breach the Belt was open from the north as far at least as the latter place.

Morlot's observations made long ago prove that the "kitchen-middens" in many cases show signs of stratification and of having

been temporarily submerged. The kitchen-middens are ordinarily 3 to 5 feet, but in some places, as at Meilgard to Kolindsund, they are 10 feet above the sea-level. Sometimes they are 1,000 feet long, with a breadth of 150 to 200 feet. In the latter cases their surface is undulating and often surrounds a depression free from them, as at Haveln, near Frederiksund, where the habitations of the natives probably were. Their interiors in most cases are unstratified.

Others found on the shore and near the waves are covered with sand and gravel, and the whole of their contents is more or less stratified, as at Biledt near Frederiksund. It is clear that in such cases the old mariners cooked their food on the shore after disembarking, and the tide has afterwards rearranged them.

Morlot again called attention to the curious circumstance that the kitchen-middens, the greater portion of whose contents are stratified, yet consist of a heterogeneous mass of shells and other debris deposited out of the reach of the waves, and sometimes have a covering of rolled and stratified materials. This is only found up to a height of 14 to 18 feet above the sea-level, and always on the slope facing the sea. At Oesterild in North Jutland this covering attains a depth of a foot, and contains pebbles as big as the eggs of a goose. Above the covering there is nothing. He concludes thus: "Il parait donc, que l'âge des *Kjoekkenmoedding* à été clos par quelque catastrophe, qui a violemment agité les eaux de la mer, laquelle a fait alors irruption jusqu'à une hauteur peu considérable au dela de son domaine habituel. Il se pourrait, que cet évènement eût eu lieu à une époque quelconque postérieure à la fin de l'âge des *Kjoekkenmoedding*. Cependant M. Steenstrup est disposé à le considérer comme marquant le terme même de cet âge."[1]

Steenstrup also argued from another side that some uplift of the coast had taken place since the deposit of the kitchen-middens, and has shown that where the shores are low and shelving the midden mounds occur at only a few feet above high tide mark, but they reach a somewhat higher level when the coast is more abrupt. This distribution of the kitchen-middens seems to show that the land has not as a whole risen or sunk very much since they were deposited, for they are not likely to have been deposited either very far from the sea or at a great level above it. So much for the kitchen-middens. Turning to the raised beaches containing the same characteristic shells as the middens, namely, the *Tapes* beds, they are found on each side of the Cattegat, both in Jutland and on the Swedish side. They increase in number as we go northwards, although of the same age. Large numbers of dead shells of the *Tapes* also occur on the floor of the Southern Cattegat. In the upper part of the Cattegat north of the island of Laesö we meet with a much more abundant living marine fauna, which closely approximates to that of the Skagerack and the Christiania Fjord, due doubtless to the greater depth and salinity of its waters. In one respect in which this approximation takes place there is no relationship whatever between the two sections of the Cattegat, and the difference is

[1] Morlot, "Études Géologico-Archéologiques en Danemark et in Suisse": Bull. Soc. Vaudoise, Sci. Nat., vi, No. 46, pp. 275–6, 1860.

fundamental and much more important. This consists in the presence in the northern part of a series of raised beaches of an entirely separate class and which have not appeared in these papers before. They are the so-called *Yoldia* beds. These beds have been much misunderstood. I shall postpone their consideration for the present and will now limit myself to the other class, namely, the *Tapes* beds, which occur here associated with a much richer fauna than they do in the southern part of the Cattegat. The greater richness in forms of these more northern beds must not allow us, however, to disguise the fact that they are otherwise quite continuous with the *Tapes* beds further south, and are earmarked by the presence of the same critical species.

In regard to the mollusca found in these *Tapes* beds of the northern Cattegat, a long list has been given by Erdmann, who says they do not occur there at a higher level than 100 to 150 feet, and are for the most part of littoral species. They are found in deposits of the so-called black clay (*svartlera*), in raised beaches and sometimes capping some of the *åsar* as in Eastern Sweden, but contain a much richer number of species and were clearly deposited under conditions of greater saltness in the water than those further south.

Erdmann, in his account of the Quaternary deposits of Sweden, gives the following list of the shells found in the black clays:—

GASTEROPODA.

Litorina litorea.
L. rudis.
L. littoralis.
Trochus cinerarius.
T. tumidus.
Natica nitida.
N. Montagui.
N. clausa.
N. Groenlandica.
N. pulchella.
N. borealis.
Emarginula reticulata.
Lacuna vineta.
L. pallidula.
Turritella communis.
Cerithium reticulatum.
C. adversum.
Odostomia rissoides.
Purpura lapillus.
Nassa reticulata.
N. incrassata.
N. pygmæa.
Aporrhais pes-pelicani.
Buccinum undatum.
Fusus undatus.
F. despectus.
Trophon clathratus, var. *minor.*
Mangelia linearis.
Rissoa ebriata.
R. labiosa.
R. ulvæ.
R. parva.
R. istrea.
R. arctica.
Patella vulgata.
Acmæa virginea.
Lepeta cocca.
Pallidum rubellum.
Dentalium (Antalis) entale.
Puncturella Noacina.
Peliscus commodys.
Philine quadrata.
Tornatella tornatilis.
Cylichna cylindracea.
C. truncata.

LAMELLIBRANCHIA.

Mytilus edulis.
Mya truncata.
Modiola modiolus.
Solen ensis.
Cyprina islandica.
Nucula nucleus.
Leda pernula.
L. caudata.
Cardium edule.
C. echinatum.
C. fasciatum.
C. Norvegicum.
Lucina borealis.
Montacuta bidentata.
Isocardia cor.
Pecten islandicus.
P. maximus.
P. septemradiatus.
P. striatus.
P. pusio.

Pecten varius.	*Cochlodesma prætenue.*
Saxicava rugosa.	*Tapes pullastra.*
S. arctica.	*Venus striatula.*
Tellina proxima.	*V. ovata.*
T. solidula.	*Scrobicularia piperata.*
T. fibula.	*Ostrea edulis.*
Syndosmya alba.	*Anomia patelliformis.*
S. intermedia.	*A. aculeatum.*
S. nitida.	*A. ephippium.*
Astarte arctica.	
A. elliptica.	*Rhynchonella psittacea.*
A. sulcata.	
A. compressa.	*Echinus droebackiensis.*
Thracia villosiuscula.	
Mactra subtruncata.	*Balanus porcatus.*
M. elliptica.	*B. crenatus.*

See GEOL. MAG., 1897, pp. 355, 361; 1898, pp. 195, 257; 1905, pp. 407, 454.

Others who have devoted some time to the exploration of the later geology of Western Sweden have described the shell beds on its shores, which point the same moral as those of Denmark, namely, their occurrence at a gradually increased elevation as we proceed northwards. In Southern Bohuslan Olbers found the shell beds at a height of 15 metres. At Stromstad De Geer found them at a height of 40 metres, while at Bullaresjön, on the Norwegian frontier, Olbers again records having found them at 48 metres high (Nathorst, *Sverige Geol.*, p. 275). (See Olbers, *Bidrag till Göteborgs och Bohuslans geologi*, Stockholm, 1870; see also on Halland, G.F.F., 1875.)

Olbers separates the deposits into two series: one of them he calls *Cardium lera*, characterized by *Cardium edule* and *C. echinatum*, *Cyprina islandica*, and *Turritella communis*, while the other, which he calls *Ostrea lera*, and which he considers to be the younger, is marked by the presence of *Ostrea edulis*, with *Patella*, *Cerithium*, *Rissoa*, etc. There are, however, local variations, due not to difference of age, but of the level at which they lived, and the differing habitat.

North of Bohuslan we reach the Gotha, a famous river, the gateway of a very interesting portion of Sweden, and specially noteworthy in view of the issues we are discussing. In an earlier page we had a good deal to say of the collapse that occurred in the lowest part of the synclinal depressions through which the Forchhammer line runs. We have now reached the part of Sweden through which another line and focus of movement runs, namely, the highest part of the anticlinal, and therefore also a district in which the tension must have been extreme and the likelihood of great dislocation very great. The Gotha River, in fact, leads us into a part of Sweden where the proofs of this are written on all sides. The Gotha itself now flows through the most tremendous gorges in Europe, the famous Trollhätten falls, which must have been caused by great breakages. They have all the appearance of being very recent and do not represent in any way the original drainage channel of the river. One fact suggesting a catastrophic cause for them is notable. The salmon which inhabit the great lakes which the Gotha drains must

once have had access to the sea at certain seasons, as is the case with these fish elsewhere. It is now imprisoned in the lakes all the year round. This is no doubt due to the cutting off of its waterway thither by the dislocations I have mentioned, which are thus proved to have been sudden and paroxysmal. The gorge is closely associated with the numerous raised beaches in the district, both on the coast and inland, and which are at an abnormal height. There is no other explanation of the presence of the raised shell beds here, but the bodily and violent uplifting of the rocks on which they lie to the height of several hundreds of feet. This is shown by a remarkable and well-known fact.

When Lyell examined the surface of the gneiss at Capellbacken immediately above the shell beds he found barnacles (*Balani*) adhering to it, showing the sea had remained there a long time and then been suddenly uplifted, for the barnacles (*Balani*) do not occur at lower levels here. Lyell says he was able to verify this observation by finding in the summer of 1834 at Kured, about two miles north of Uddevalla and about 100 feet above the sea, a surface of gneiss newly laid open by the removal of a mass of shells used largely for making lime, etc., with the barnacles (*Balani*) so firmly adhering to the gneiss that he was able to break off pieces of the latter with the shells attached. The face of the gneiss was also covered with Bryozoa. Other beds with the same shells occur near Uddevalla, others again on the opposite island of Orust, as well as in that at Tjörn and at points on the coast still further south (*Principles of Geology*, ii, 192).

While this is the evidence of the barnacles (*Balani*) in regard to the uplift of the rocks themselves, the evidence of the shells in the raised beaches is also most impressive. I have spent a considerable time among them on the spot and I have never seen anything like them. The number of different species coming from several zones of very different depths is phenomenal. Gwyn Jeffreys collected eighty-three species. They occur here in immense masses which have been largely quarried, not mixed with sand and clay, but for the most part washed clean; quite different, therefore, from any deposits in the beaches to be found on ordinary shores.

They are also very perfect and quite unweathered. I have a large collection of them, exceedingly few of which are broken, and there are a great many very fragile and tender shells such as big specimens of *Pholas*, with their internal hooks quite intact, among them. Attempts have been made to sort them out into different zones by Gwyn Jeffreys, but they have signally failed, as Brögger allows. If they were the current deposits of different periods they would not lie as they do in juxtaposition. The only solution of their condition and position is that they were collected by some great tidal wave from a sea bottom of varying depth. These shells are also of the most recent types, and except one or two insignificant varieties all are living in the adjoining seas. To my own eye nothing I have seen of the kind presents more complete evidence of the solidarity of the beds in regard to the time and method of deposit. May I add that the fact of the *Balani* remaining attached to the polished

rocks, and as fresh under their covering of shells as if recently dead, and showing no signs of weathering, absolutely proves to me that they were not exposed to the weather during a gentle or long-enduring elevation, but were lifted up suddenly by one impulse with the rocks to which they are attached and at once covered by the protecting shell beds to the height of 200 feet above sea-level or more. They attest most completely the cataclysm which must have occurred when the great Swedish anticlinal was lifted bodily up.

Several of the great Scandinavian rivers, says Reclus, have changed their courses. There was a time when the River Foenmund, now draining southward to the Cattegat through the River Klar, drained through the Dalelf south-east to the Gulf of Bothnia. The old bed of the river is still visible four or five feet above the present lake. The Gotha was recompensed by receiving from another source all the waters of the Glommen, so that its volume was more than doubled.

The extent of country, too, where the shells have been found at high levels in Central Sweden is very great; they have been found in Jemteland, West Gothland, and Dalsland, while on the heights commanding the Lakes Wener, Wettern, and Mjösen, and the Mälar Sea great beds of oysters occur, showing how much of the high land there has been submerged. These great lakes have clearly been lately united and formed a great gulf which was in fact an extension of the Cattegat. This was clearly seen and stated long ago by Lyell.

In his Bakerian Lecture, printed in the *Philosophical Transactions* for 1835, Lyell said it is evident from the position of the fossil shells of several species on the coast of the Baltic between Gefle and Södertelje, and on the shores of the ocean between Uddevalla and Gothenburg, that the tract of land which once separated the two seas in this region was much narrower at a comparatively modern period. Shells like those at Uddevalla have not only been found a few miles due east of that place, but as far inland as Trollhätten, in digging the canal there, and still further in the interior, about fifty miles from the coast at Tuscdalersbacken and other places near Rogvarpen in Dalsland on the west side of Lake Wener. Of these matters an account is given by Hisinger (*Anteckningen*, iv, 42). They are found in Dalsland as far above the sea as near Uddevalla, or about 200 feet high, so that when deposited we must suppose the whole of Lake Wener, the surface of which lies at an inferior level, to have formed part of the ocean.

Another evidence of the extent of dislocation will be referred to presently when we discuss the so-called *Yoldia* sea and the distribution of that much misunderstood and very important shell in the district we are considering, where it has been found at great heights and yet must have lived at very great depths.

The contours and great depths of the Swedish lakes and their abnormal living contents also go to show that quite recently geologically they have been united and that they have been subject to disruptive movements. Although their surface is above the level of the sea the beds of most of them are much below that of the Baltic

Wener has a mean elevation of 144 feet, while its extreme depth is 290 feet; Wettern is twice the altitude of Wener and is also deeper, measuring 417 feet in depth and being 126 feet below that of the adjoining sea. The Mjösen Lake, which is 197 square miles in extent, has an extreme depth of 1,480 feet with an altitude of 397.

The curious fish and crustaceans contained in these lakes have been accepted as relics of former conditions when they formed part of the gulf already mentioned and when it was occupied by salt water, and they have since adapted themselves to freshwater conditions. The Norwegian lake of Mjösen, although it is so far distant from Lakes Wener and Wettern, also contains one of these relics in the form of *Mysis relicta*.

The evidence therefore abounds that in that part of Sweden where the upheaval has been the greatest there are the most potent proofs that it culminated in great changes of the earth's crust on a mighty scale at a very recent period. This must, it is clear, be taken into account as a postulate when we are analysing the later geological history of the country. It seems to me also that subsidiary evidence of these fractures and breaks is to be found in the utterly smashed condition of the Silurian beds in the upper parts of the Baltic region, the broken and angular debris of which have been so widely scattered, and also the existence of so many beds of quite sharp-edged unaltered stones, the equivalents of the angular drift of the English southern coast lands, which it would seem impossible to account for except as the result of enormous impacts caused by spasmodic movements.

Let us now proceed further north. We have reached the frontier separating Sweden and Norway. The political frontier-position corresponds to no definite physical one. There is complete continuity in the geology across the political "divide" so far as it relates to the latest period. The raised beaches are clearly contemporary in the coast-lands of Bohuslan and Central Sweden and those of the great inland bight or gulf formed by the Skagerack on the west and the Cattegat on the east, with the projecting pocket known as the Christiania Fjord. In both cases we have two definitely separated sets of raised beaches, one containing only a highly Arctic fauna and existing for the most part at a low level and the other characterized by the same fauna as still lives in the bight and for the most part at high levels. The details of the phenomena have been set out in an excellent and portly volume by Dr. Brögger on *The Raised Beaches of the Christiania Fjord*, to which I am greatly indebted.

Before dealing with these details, however, I propose to say a few words in regard to the more general question in which Norway as a whole has the same story to tell as Sweden.

The first point in which they agree is that both contain the strongest evidence that the land has been quiescent for many centuries. In a notable paper by Hansen, the latest authority on the subject in Norway, he first calls attention to the divergent opinions of older inquirers in both countries on the matter, and points out the uncertainty in obtaining fixed elements to enable the problem

to be definitely solved, namely, the variation of the barometric pressure, the height of the Atlantic tide, and the potency of the wind. These make it difficult to fix any norm or index by which to measure permanent changes of level, and he turns his inquiries from the physical data to archæological evidence as affording a more satisfactory result inasmuch as it enables us to cover a much longer period of observation.

From the close of the Bronze or beginning of the early Iron Age, we have cairns very near the present beach, and from the later Iron Age we have also other fixed relics along the coast, which are now quite as near the sea-level as it is possible for them to be. From these it must be concluded, says our author, "that the sea-level has not been subjected to any permanent secular change on the Norwegian coast in the last millennium, very likely not in the last two thousand years" (op. cit., p. 110). Some critical examples may be quoted in support of this generalization: Everest, in his travels in Norway, informs us that the Island of Munkolm, an insulated rock in the harbour of Trondhjem, proves that the land there has not altered in level for eight centuries. The island is not larger than a small village. By an official survey the highest point is only 23 feet above river high-water mark, and a monastery was founded there by Canute the First in A.D. 1028, and thirty-eight years before that it was used as a place for execution (Lyell, *Principles*, ii, p. 195, 1875).

In regard to the rate of the rise, Hansen again says: "The present shore-line in Norway is of considerable age. It is impossible to believe that the present clearly defined, strongly developed beach extending from high to low water has been formed under any (however slow) secular shifting of the sea-level. The rocks immediately above show in some places the work of the breakers, which cannot be observed higher up, and the surface-profile in loose material does not answer at all to a regular rise of the land" (ibid., pp. 110–11). It is plain, therefore, that the raised beaches of Norway, as of Sweden and Britain, point to the land having been long quiescent, while they index a period when the earth was subjected to great movements, which nevertheless were contemporary with the present marine fauna in the North Sea. These movements virtually ceased hundreds of years ago. In Norway, as in Sweden, therefore, we have the same kind of evidence that the uplift has not been continuous but spasmodic, which is again revealed by insulated raised beaches separated by stretches void of such testimony. They occur at different levels in different places, but as far as we know synchronous. The culminating point of the raised beaches with shells on the west of Norway is in the Trondhjem Fjord, where they reach to a height of 600 feet. There, as in Sweden, they descend in level both as we travel northward and southward. Von Buch, in the Breistad Fjord, some distance north of Trondhjem, found marine shells 140 feet above the sea-level (*Reisen*, pp. 1–251). M. Eugene Robert describes how, in the Island of Ham between North Cape and Hammerfest, he had found a great alluvial deposit running with a gentle slope to a height of more than 101·7 feet, and showing

seven stages or terraces faintly marked, formed of marine pebbles placed one behind another and separated by turfy soil. The whole of this system, he says, rests upon a thick layer of the debris of shells, among which we perceive fragments of *Cyprina islandica* and other molluscs, identical with those now living in the Polar ocean. It is the same with regard to the Island of Qualse, and we have there an additional curious point, namely, his discovery in a depression behind the gate of the town of Hammerfest, and at a height of about 82 feet above the sea a number of erratics, the interstices between which are filled with small pieces of blackish pumice-stone, similar to those which continue to be thrown ashore from time to time, even in the present day, on the coast of Norway, along with floating wood, whose origin is evidently to be assigned to the volcanic eruptions of Iceland, or of that of Jan Mayen (Chambers, *Sea-Margins*, pp. 286–7).

Bravais ("Former Sea-level in Finmark": Q.J.G.S., i, p. 544, 1845) points out how in Finmark the shell beds occur at a much lower level than further south. At Talvig, by digging about half a metre below the surface in a sheltered part of the bay, he laid open a clayey bank containing *Mya truncata* and *Tellina Balthica*, some of the specimens being remarkably fresh and even showing vestiges of the epidermis. This bed was 7 metres only above the sea-level and appeared identical with one described by M. Keilhau. "I have likewise," he says, "received other shells (*Patella* and *Venus*) collected near Storvig, at the western extremity of the Island of Söröe, in a sandy deposit a few metres above the level of the sea. The elevation in this case was about 30 metres."

A similar drop in the shelly beaches has been noticed in proceeding southwards from Trondhjem, showing that the movement of the land in Western Norway (as in Sweden) has been differential, with a culminating point at Trondhjem.

(*To be concluded in our next Number.*)

IV.—The Stratigraphical Position of the Coralline Crag.

By F. W. Harmer, F.R.Met.Soc., F.G.S.

In an interesting paper lately published[1] my friend Mr. R. B. Newton has expressed the opinion that the Coralline Crag should be grouped with the Diestien and Anversien of Belgium as Upper Miocene, the fauna of the Suffolk boxstones being regarded by him as Middle Miocene. The recent researches of Mr. Alfred Bell[2] have led me to agree with Mr. Newton that the latter is pre-Pliocene, but I regret I cannot accept his view as to the age of the Coralline Crag, which I consider to be more nearly related to the Waltonian horizon of the Red Crag than to the Belgian Miocene.

In the introduction to my Memoir on the Pliocene Mollusca of Great Britain, now in course of publication (pt. i, p. 5), I proposed

[1] Journ. of Conch., vol. xv, p. 115, 1915.

[2] Geol. Mag., Dec. VI, Vol. IV, p. 407, 1917; Vol. V, p. 15, Pl. III, Figs. 3, 4, 1918.

the following classification of the various divisions of the Anglo-Belgian deposits, to which, with the exception of the point alluded to above, I still adhere:—

Upper Pliocene.

Belgium and Holland.		*England.*
Amstelien.		Butleyan and Newbournian.
Poederlien	Waltonian.	Walton horizon.
Scaldisien		Oakley horizon.
Casterlien (zone à *Isocardia cor*).		Coralline Crag.

Lower Pliocene.

Diestien (zone à *Terebratula grandis*). Lenham Bed.

In his synoptical list of 1874[1] Wood reported 430 species of Mollusca as known to him from the Coralline Crag; of these only about 90 had been found at that time at Walton, but even then he had come to the conclusion that there was a close connexion between the two deposits and that his original reference of the former to the Miocene had been a mistake.

The investigations of Professor Kendall and the late R. G. Bell at Walton and my own at Little Oakley have strongly supported Wood's later opinion. Of the 430 Coralline Crag species referred to, about 270 are now known from the Waltonian or some later horizon, while hardly any of the remainder can be considered common or representative Coralline Crag forms. To regard a species of which only one or at the most a very few specimens have been obtained during the labours of a century as of equivalent value, for purposes of analysis, to others of which a large number could be found at any time in a few days, is misleading. It is by the general facies of a fauna—by the abundant and not by the rare examples—that we should be guided.

While, therefore, nearly all the characteristic Coralline Crag species continued to exist in the Anglo-Belgian basin during Waltonian times, or even to a later period, no such correspondence can be traced between its fauna and that of the Belgian Miocene, zones à *Panopæa Menardi* and *Pectunculus pilosus* of Van den Broeck (Anversien, Newton). Out of 230 species of mollusca reported from the latter horizon by the former observer, only 106 are known from the Coralline Crag, the rest being generally and distinctly of an older type.[2]

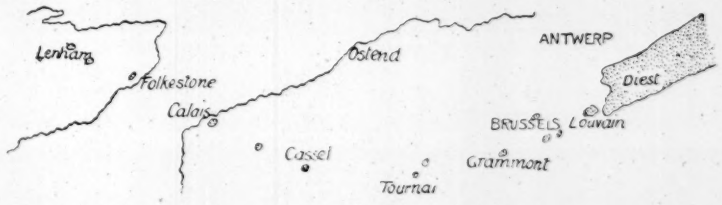
The true Belgian equivalent of the Coralline Crag is the zone à *Isocardia cor*, the fauna of the two being practically identical. Of about 150 species given by M. Van der Broeck[3] or M. Bernays[4] from the latter (for which I have revived the name of Casterlien), all but about half a dozen have been obtained from the Coralline or the Waltonian Crags. The Casterlien, moreover, bears a relation to the

[1] Mon. Crag Moll., 1st Suppl., pt. ii, p. 203, 1874.
[2] Ann. Soc. malac. Belg., vol. ix, pp. 118, 134, 1874.
[3] Op. cit., p. 187; Bull. Soc. Belge Géol., vol. vi (Mém., pp. 120, 130, 1892).
[4] Bull. Soc. Belge Géol., vol. x (Mém., p. 128, 1896).

Scaldisien of Belgium similar to that between the Coralline and Waltonian Crags. A reference to lists of fossils from all these beds shows that the connexion between the Coralline–Casterlien and the Waltonian–Scaldisien deposits is as clearly marked as is the difference between the former group and the Anversien (Miocene) of Belgium.

In a well-known work the late Mr. C. Reid identified the Lower Red Crag with the Astian and the Coralline with the Plaisancian of Piedmont, placing the one in the Upper, the other in the Lower Pliocene.[1] In the light of our present knowledge I cannot see any sufficient reason for such a division of these East Anglian beds, all of which I continue to regard as Upper Pliocene. The introduction to the Anglo-Belgian basin of some northern mollusca during the Waltonian period while many southern and Coralline Crag species continued to linger on was due, I think, to the tectonic movement described in one of my former papers, by which the Crag sea was brought then and for the first time under the influence of marine currents from the north.[2]

I agree with Mr. Newton that the Lenham fauna is older than that of the Coralline Crag, though I don't think that anyone who has a working knowledge of the subject could regard the list of Lenham fossils given by him or the specimens on his plates as a typical collection of Coralline Crag fossils. I hesitate, however, to regard them as Miocene. Stratigraphically they are connected with the sands of Louvain and Diest (zone of *Terebratula grandis*) by a remarkable series of isolated remnants of that deposit (as shown on the annexed map, copied from one of M. Rutot's), which form a curved line, extending roughly from west to east, through Folkestone, Calais, Cassell, Tournai, Grammont, and Brussels.



Sketch-map showing the connexion between the Lenham Bed and the Diestien sands of Louvain and Diest (after Rutot).

The Diestien sands have been always regarded as Pliocene by Belgian geologists. Until now I have never heard it suggested that they are Miocene, but if the stratigraphical evidence is of any value and the Diestien beds are Pliocene, the Lenham Bed must be Pliocene also, though Lower and not Upper Pliocene as is, I submit, the Coralline – Casterlien group. They contain some characteristic Miocene or Lower Pliocene species unknown from the Coralline Crag, but they contain also a considerable proportion of a more recent

[1] *Pliocene Deposits of Great Britain*, 1890, pt. i, p. 5.
[2] Quart. Journ. Geol. Soc., vol. lii, p. 761, fig. iv, 1896.

character which it seems to me would be out of place in a typical Miocene deposit.

Leaving on one side the northern species which appear to have been more or less suddenly introduced into the Crag basin under the influence of the tectonic depression alluded to, and counting specimens rather than species, there is a general resemblance between the fauna of the Coralline Crag and that of Walton which does not exist between those of the former and of Lenham. For zoological as well as for stratigraphical reasons I draw the line separating the Lower and the Upper Pliocene divisions of the East Anglian deposits between the Coralline Crag and the Lenham beds rather than between the former and the Waltonian.

I agree to some extent with Mr. Newton as to the age of the block of fossiliferous limestone described by him in 1917.[1] From a very superficial examination I formed a strong impression that it was pre-Pliocene, but I cannot admit, on the other hand, that it has anything to do with the Coralline Crag. It reminded me of some fossiliferous blocks which some years ago Mr. Van Watenschoot van der Gracht informed me were occasionally dredged in the North Sea. He seemed at that time to be under the impression that they were of Oligocene age.[2] I believe a collection of fossils had been made from them which were then at The Hague. Hereafter it may be possible to compare these Dutch specimens with those identified by Mr. Newton. It seems not unlikely, moreover, that the latter may be of a similar character to those found by Mr. Nörregaard in some erratic boulders of Middle Miocene age obtained from a glacial clay near Esbjerg,[3] but this could be probably ascertained without much difficulty.

Although I do not agree with the classification adopted by Mr. Newton, I welcome his recent papers as calling attention to an important series of deposits in which formerly much interest was taken, but of late years have been almost entirely neglected.

V.—On Successive Stages in the Denudation of the Chalk in East Anglia.

By Herbert Arthur Baker, B.Sc., F.G.S.

A RECENT attempt by the writer[4] to utilize the information at present available with a view to gaining some notion of the dominant characteristics of the denudation suffered by the Chalk of the London Basin prior to the deposition of the Eocenes yielded results of sufficient interest to encourage him to apply the same method of analysis to the East Anglian area.

Sufficient data for the construction of a provisional map showing the isopachyte system of the Chalk of this area lie to our hand,

[1] Quart. Journ. Geol. Soc., vol. lxxii, p. 7, 1917.

[2] I understand that there is some difference of opinion among Continental geologists as to the correct division between the Oligocene and Miocene of Northern Europe.

[3] Danm. Geol. Undersögelse [4], No. 5, p. 58, pls. i–iii, 1916.

[4] Baker, Geol. Mag., July, 1918, pp. 296–305.

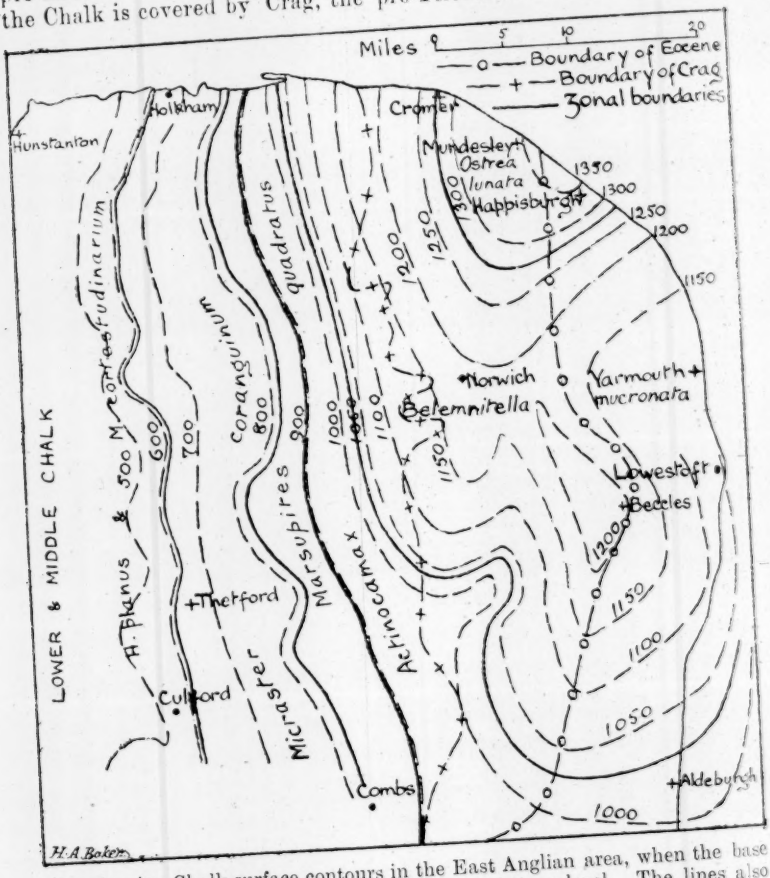
although, so far as the writer is aware, there is as yet no map giving direct information concerning the variation in thickness of the formation.

We are in possession of a certain amount of information, from deep wells and borings, concerning the level of the base of the Chalk at various points throughout the area. While wishing that this information were more abundant we need not be deterred from proceeding with the investigation. Committing our data to paper and considering the items of information correlatively, we find that the base of the Chalk appears to slope away in a general east-north-easterly direction with remarkable uniformity, dropping at the rate of about 24 feet to the mile, throughout the whole of the eastern portion of the area. Further west the contours take on a slight sinuosity, assume a more or less north and south direction, and become somewhat more closely spaced, indicating an increase in the gradient. Since in the construction of this map we are able to use the information supplied by only about half a dozen levels, it follows that in our use of it we must not expect a greater degree of accuracy than it is capable of yielding. But our confidence in the utility of the map for the purpose which follows is maintained when we observe that it so happens that the available levels are well distributed, and further, that the contours over a great part of the area are practically straight lines.

Having represented cartographically our information concerning the level of the base of the Chalk, we next require a similar representation of our knowledge of the present level of its surface, and this we find to our hand. The Chalk-surface contours of this area have been mapped by Professor P. G. H. Boswell,[1] and we are able to avail ourselves of the results of his labours. If the base of the Chalk were "corrected" in such a way as to cause it to occupy a horizontal plane at sea-level, and the Chalk surface were modified correspondingly, then lines joining points at which the surface of the Chalk is at the same height above the base of the formation would constitute the isopachyte system which we seek. We therefore superimpose the Chalk-surface map upon that showing the level of the base of the formation. At points where the contours intersect, the amount of correction necessary to bring the base of the Chalk to sea-level is indicated by the one map, and the appropriate correction is applied to the other. The completed series of lines thus obtained constitutes our provisional idea of the variations in thickness of the Chalk in East Anglia, and is shown in the map here presented. The sources of error are manifold, but every incorporated item of additional information will bring the final result nearer to the truth—and however inaccurate the present map, it at least provides us with a notion of the general character of the isopachyte system of the East Anglian Chalk which we could never have conjured up had the attempt not been made—and, further, by its aid certain salient characteristics of the denudation undergone by this Chalk area jump at once before the eye.

[1] Boswell, Q.J.G.S., vol. lxxi, pl. 1.

In our study of the map it is helpful to bear one consideration in mind. It is a fair assumption to make that, at the beginning of Eocene times and again at the beginning of Pliocene times, the base of the Chalk in this area did not deviate markedly from horizontality. Consequently the lines upon our map give, for the area where the Chalk is yet covered by Eocene, a generalized representation of the pre-Eocene contours of the Chalk surface, and for the area where the Chalk is covered by Crag, the pre-Pliocene contours. For that



Map showing Chalk surface contours in the East Anglian area, when the base of the Chalk is corrected to horizontality at sea-level. The lines also serve as the isopachytes of the Chalk.

area where the Chalk is bare the lines serve to indicate the stage to which its denudation has proceeded at the present day.

With regard to the pre-Eocene Chalk-surface contours, the most outstanding features are that there appears to be a drop from the figure of 1,350 feet at Happisburgh down to 1,000 feet at Aldeburgh, and the prevailing direction of the lines is N.E.–S.W. There can be very lttle doubt but that we have here the last remaining evidence

of the escarpment which in pre-Thanetian times faced south-eastward and stretched away many miles to the west and south. Between Yarmouth and Aldeburgh there appears to be evidence of a drop to the eastward, which is most clearly shown between Beccles and Lowestoft, but we are hardly in a position to place much confidence in any explanation put forward concerning this interesting and somewhat unexpected feature. The writer thinks it not unlikely that, along a N.W.–S.E. line traversing the central part of the Norfolk area, there was, during the deposition of the Chalk, a definite movement of depression, whereby a greater thickness of sediment was deposited vertically above this line than was laid down farther east. If this was the case, the severity of the denudation suffered by the Chalk in the central portion of the area is still further emphasized.

The evidence of an advancement in the stage to which the denudation of the Chalk proceeded during post-Eocene and pre-Pliocene (i.e. Miocene) times, is very striking. The earth-movements which were in operation in Miocene times, governing the general character of the denudation, were, in this area, different in their direction from those whose activity resulted in the production of the old E.N.E.–W.S.W. pre-Eocene escarpment. A movement of uplift along an axis traversing the central part of Norfolk, and disposed in a general N.W.–S.E. direction, appears to have taken place, and denudation proceeded in such a way as to produce an escarpment facing west and making a pronounced feature in the landscape. A strong valley was eroded in the Chalk in pre-Pliocene times, but we are not in a position to state the age of the abrading stream with any precision. It may have been initiated in pre-Eocene times and perhaps entered the area at a spot somewhere between Happisburgh and Yarmouth. On the supervention of the new movement of uplift fresh river-systems were initiated, which are those of the present day, and one stream, the Waveney, throughout a part of its course, actually occupies the site of the old valley, thus providing us with an interesting illustration of reversal of drainage. The severity of this post-Eocene and pre-Pliocene denudation of the Chalk is well brought out by the map. Where the isopachytes emerge from beneath the Eocene cover they change direction most abruptly and exhibit a very pronounced tendency towards parallelism in a general N.W.–S.E. direction. A considerable thickness of chalk must have been removed from the exposed portions of the formation during this time, particularly in the northern part of the area. With the advent of Crag times a further portion of the chalk surface was covered, and that part which is yet concealed beneath the Crag has, of course, escaped all post-Pliocene denudation. This post-Pliocene denudation has effected the removal of much of the Crag cover and carried the attrition of the chalk beneath it to a still more advanced stage.

In addition to bringing out the interesting points already considered, our map is of service in enabling us to insert the boundaries of the outcrops of the successive zones of the Chalk, for unless the zones vary in thickness throughout the area, the

outcrops of the successive boundaries will be in parallelism with the lines on the map. To take the case of the small area where the Chalk surface is composed of the *Ostrea lunata* zone, Professor Boswell has estimated[1] the maximum thickness of this zone before it is overlain by Eocene deposits to be between 70 and 80 feet. Consequently, on our map, the boundary between this zone and that of *Belemnitella mucronata* will occupy a position between the 1,250 and 1,300 lines. Similarly, adopting Professor Boswell's estimate of 240 feet as the thickness of the *B. mucronata* zone at the point where the Eocene comes on, this will bring the position of its lower boundary on our map between the 1,000 and 1,050 lines. In the same way, assuming the estimated thickness of about 135 feet for the *Actinocamax quadratus* zone, its lower boundary will coincide roughly with our 900 line; that of the *Marsupites* zone, if its thickness is between 60 and 70 feet, as Professor Boswell estimates, will occur somewhat to the east of our 800 line; and that of the *Micraster coranguinum* zone, if its thickness is 210 feet, will occur a little to the east of our 600 line. The insertion of these zonal boundary-lines on the map brings out well the unconformities between the Eocene and Chalk and Pliocene and Chalk respectively, but particularly that of the former, since the Eocene is seen transgressing from *Ostrea lunata* Chalk in the north, across *B. mucronata* Chalk, on to *A. quadratus* Chalk in the south.

Immediately to the south of the area under present discussion there occurs a notable disturbance of the Chalk, but the consideration of this feature lies outside the scope of the present brief paper.

REVIEWS.

I.—The Palæontographical Society.

THIS Society has just issued, for 1916, its seventieth volume (dated February, 1918), containing:—

1. The Wealden and Purbeck Fishes. Part II. By Dr. A. S. Woodward, F.R.S. pp. 49, with 10 plates and 14 text-figures.

2. The Pliocene Mollusca. Part III. By F. W. Harmer, F.G.S., etc. pp. 159, with 12 plates.

3. The Palæozoic Asterozoa. Part III. By W. K. Spencer, M.A., F.G.S. pp. 59, with 8 plates and 48 text-figures.

4. British Graptolites. Part XI. By Miss Elles, Sc.D., and Miss Wood (Mrs. Shakespear), D.Sc. Edited by Professor Lapworth, LL.D., F.R.S. pp. 60, with title-page and index.

The volume before us, literally produced "amidst war's alarms" (for the premises of Messrs. Adlard & Son, the printers, were upon one occasion bombed by an enemy aeroplane), displays neither in the quantity of its contributions nor their quality in authorship, illustrations, printed matter, or paper any deterioration as compared with

[1] Boswell, "Notes on the Chalk of Suffolk": Journ. Ipswich and District Field Club, vol. iv, pp. 17–26, 1913.

the long series of seventy volumes with which it now takes an honourable place. Nor has the modest annual subscription of one guinea been increased, notwithstanding the advanced price in printing paper and illustrations and labour prevailing since the War.

In his monograph on the Wealden and Purbeck Fishes (part ii) Dr. Arthur Smith Woodward gives an admirable series (pl. xi) of the remarkable rows of small enamelled round, crushing, palatal teeth in *Lepidotus Mantelli* (one of the most characteristic of Wealden fishes), showing the mammaliform apices and successional teeth in sockets; also the large flank bony-enamelled scales (square or rhomboidal in form), fixed in place and pegged down by bony processes like the slates upon a house-roof (described in part i, 1915). The genus *Mesodon* of Middle Purbeck age from Swanage, etc., with its allied genera *Eomesodon* (Lias and Portlandian), *Microdon* (Purbeck), and *Cœlodus* (Lower Cretaceous and Purbeck), introduces us to a singularly interesting series of Pycnodont fishes with flattened sides more or less covered by enamelled rhomboidal scales with small protruding, often beak-like, mouths and crushing teeth well adapted to feed upon coral-zoophytes, crustacea, and molluscs. This group of Mesozoic fishes is remarkably well preserved in the lithographic rocks of Solenhofen, the Purbeck of England, and down to the Lias, and without imaginary evolution the author is able to give us on p. 49 an actual picture of *Mesodon macropterus*, as seen in life, correct in every anatomical detail. There are numerous other valuable text-figures, as well as ten plates drawn by Gertrude M. Woodward, which add much to the interest of this important monograph.

The third instalment of Mr. Harmer's fine monograph of Pliocene Mollusca maintains the high standard of the earlier parts, both in the careful preparation of the author's text and the very excellent quality of the collotype plates executed by Mr. J. Green. Mr. Harmer has been at infinite pains to trace the past history of each species with its geological and geographical distribution and the collections in which specimens are preserved, and in case of survivals their present habitats. Many forms also are now figured and described which occur in widely varied British and foreign localities, far beyond East Anglia, which region gave birth to the parent Crag monograph by S. V. Wood half a century or more ago.

In Mr. W. K. Spencer's monograph on the Palæozoic Asterozoa much attention is given by the author to the anatomical details of structure upon which their zoological arrangement depends; indeed, the external forms as shown in six out of the eight plates would hardly suffice without the explanatory structural figures given in the forty-eight text-illustrations and the anatomical details so carefully delineated on pls. vii and viii (some of those on the plates being perhaps needlessly large for the purpose of study, e.g. fig. 2, pl. vii, and figs. 1, 2, and 7 on pl. viii). On the other hand, such a beautiful form as *Lepidaster Grayi* (fig. 1, pl. vii) might well have been more enlarged to show its details to advantage.

We congratulate the Misses Elles and Wood (Mrs. Shakespear) and Professor Lapworth on the completion of their elaborate

monograph on British Graptolites. Part i was commenced in 1901, and now by the issue of part xi, containing title-page and index and 23 pages of "Historical Research", their labour, extending over fifteen years, is happily completed. We heartily rejoice with the threefold authors in the consummation of their most difficult task. Of the usefulness of such a great work we prophesy future generations of students of palæontology will arise to bless the authors, and also to support the Society as subscribers. Many too, we trust, will likewise be found to add some good work to further the object of the founders of the Society, namely, "to figure and describe every species of British fossil."

II.—Memoirs of the Geological Survey.

Special Reports on the Mineral Resources of Great Britain. Vol. VI: Refractory Materials: Ganister and Silica-Rock—Sand for open-hearth Steel Furnaces—Dolomite—Resources and Geology. pp. vi + 233, with three maps. London: T. Fisher Unwin. 1918. Price 7*s*. 6*d*. net.

IN this, the sixth volume of the reports on the mineral resources of Great Britain, we have the first part of what promises to be a comprehensive account of refractory materials. The greater part of the memoir is occupied by the descriptions of the raw materials used in silica-brick manufacture. These comprise various rock-types, including quartzite, siliceous sandstone, "Dinas rock," "ganister," "crowstone," etc., and in a somewhat similar fashion the manufactured materials are classified as silica-, ganister-, and Dinas-bricks. Unfortunately, such words as "ganister" and "crowstone" are miners' terms, and, owing to their use being local, their exact significance is not well defined. The word "ganister" originally applied to the silica-rock on a particular horizon in the Lower Coal-measures of the Sheffield district, has never been satisfactorily defined, and it is doubtful whether the definition given in the memoir settles the question.

It is impossible to use as the main criterion the geological horizon, as not only does the rock vary in different areas but rocks practically indistinguishable from it are found on other horizons in other localities. The rock must be defined in terms of its petrographical characteristics, but in order that such definition be generally adopted, it must contain references to those properties which determine the utility of the rock as raw material for silica-bricks. The Geological Survey definition is practically a petrographical description of the typical Sheffield rock, but little attempt is made to take into account the latter consideration. There is no doubt that the chemical composition, size and shape of the quartz-grains and the amount and nature of the impurities are of great importance so far as the refractory properties are concerned, but the distribution of these impurities and the nature of the thin layers between the grains must also be considered, owing to their probable action as accelerators of the inversion of the quartz to the high temperature forms, cristobalite and tridymite. Owing to the great expansion

during these inversions, the best rock, other things being equal, is that in which as much of the quartz as possible can be transformed during manufacture and which therefore will show the smallest after-expansion in use. It is improbable that a really satisfactory definition will be obtained until more is known concerning the petrological properties which determine the usability of the rock.

In the introductory chapter an account of the manufacture of silica-bricks is given, and this, considering its condensed nature, is satisfactory except with regard to the temperatures to which the bricks are fired. It is stated, for example, that in North Wales these range from cone 16 to cone 29, but these figures are much higher than those attained in general practice. It is very doubtful whether first-grade silica-bricks are ever fired in this country at temperatures above cone 16, and this can be verified by a comparison of British and American bricks. The latter are rarely fired above cone 17 or 18, and, even taking into account the more prolonged firing, the much smaller proportion of unconverted quartz which they contain, in comparison with the former, can only be explained by the lower temperature to which the British bricks have been subjected during firing.

The major portion of the memoir is taken up by an account, with details of the occurrence, methods of working, reserves, etc., of the mines and quarries in which siliceous rocks are obtained, short petrographical descriptions of the rocks being appended. The qualitative nature of the latter militates against the utility of the results. It is greatly to be regretted that practically no chemical details are given and also that the refractory tests mentioned in the preface as having been carried out are deferred, apparently to a later volume. These data would have been much more useful if they had appeared with the descriptive part. The latter seems to be fairly accurate and detailed so far as the materials already being worked are concerned, but the information regarding untouched English sources is very meagre, though there is a chapter on "potential" Scottish supplies.

In a chapter devoted to an account of the sand and clay pockets of the Peak District, the geological age of the deposits is given as possibly "post-Triassic and pre-Glacial", while in a table earlier in the volume they are characterized as "post-Glacial". As a matter of fact, the post-Triassic age of some of these deposits cannot be regarded as definitely proved.

The remainder of the volume describes the British deposits of sand suitable for open-hearth steel furnaces, and of dolomite for lining converters, the beds of open-hearth furnaces, etc. In connexion with the paragraph on the decalcification of dolomite, some recent work on the Grenville (Quebec) deposits may be noticed. Where the material is a mixture of magnesite and dolomite, it is possible to increase the proportion of magnesia by "slaking" the calcined minerals, but it has not been found possible to vary the proportions of lime and magnesia by this method in dolomite alone.

The editing of the collected information has, as usual, been well done, though a few misprints occur: for example, the spelling

"Eccleshall" should refer to the Staffordshire place of that name, the Sheffield place being usually "Ecclesall". Even when the increased costs of publication are considered, the price seems somewhat higher than necessary.

A. S.

III.—Geology of a Portion of the Flathead Coal Area, British Columbia. By J. D. Mackenzie. Geological Survey of Canada, Memoir 87, 1916. pp. ii + 53, with 1 plate and 2 maps.

THIS coalfield lies on the western side of the Flathead Valley, a little over 2 miles north of the 49th parallel, and 35 miles by road from Corbin Station, on the C.P.R., the nearest railway station in Canada. The Flathead Valley runs north and south, and is a rift faulted in between the Clarke and Macdonald ranges of the Rocky Mountains. The coal area, which is about 4½ miles long by 3½ miles wide, is let down into the western side of the valley by two parallel normal faults striking N.W.–S.E.

This district includes rocks from Devono-Carboniferous to Upper Cretaceous, all of which lie on one another in apparent conformity, a few Eocene lacustrine deposits and moraines and glacial drift.

The coal-bearing formation is the Kootenay, of Lower Cretaceous age. This consists of about 1,100 feet of grey and brown sandstones and shales, which contain 80 feet of coal. The productive measures are all situated in the lower 400 feet of the series and contain five seams which are respectively 4, 7, 8, 25, and 36 feet thick. From the included fossils and the character and distribution of the rocks it is inferred that the Kootenay Series was laid down in a string of lakes or swamps along the main axis of the Rocky Mountain Chain. The coal is bituminous and soft, but on the whole of good quality, though the full thickness of the seams is not workable in all cases. The mines are still in the prospecting stage, but the conditions and quality are such that mining will be profitable as soon as railway transport is provided. In addition to the coal some thin lignite seams occur in the Tertiary beds, but these are not of any value. Also globules of bitumen have been noticed in the finer-grained calcareous beds of the Tertiary formation, which are supposed to indicate the presence of petroleum. Some prospecting has been carried out in these rocks, but no oil has yet been found.

W. H. W.

IV.—Reports on certain Minerals used in the Arts and Industries: Graphite. By P. A. Wagner. South African Journal of Industries, February, 1918.

THIS paper contains a good account of the properties and uses of graphite, with a detailed description of the South African sources of supply. Although these are not very large, they are at present supplying a considerable part of the local demand. The only locality actually being exploited is situated in the eastern portion of the Zoutpansberg district of the Transvaal. Here the mineral occurs as a lens lying between pyroxenite and quartzite. Samples assayed from 50 to 90 per cent of carbon, and several

different grades are now on the market. Several other occurrences are known in the Transvaal and Natal, but they do not seem to be of much commercial importance.

V.—Asbestos. By P. A. Wagner. South African Journal of Industries, November, 1917.

FOUR principal varieties of asbestos are recognized, namely, chrysotile-asbestos, tremolite-asbestos, crocidotile-asbestos, and iron-amphibole. All of these occur in South Africa, the first in Rhodesia, the second in Zululand, the third in Griqualand West, and the last in the Transvaal. The reserves of chrysotile-asbestos in Rhodesia and of crocidolite in Griqualand West are enormous, and there seems to be every prospect of an important and flourishing industry in the near future, likely to compete with Canada as the world's greatest producer.

VI.—The Zones of the Karroo System and their Distribution. By A. L. du Toit. Proc. Geol. Soc. South Africa, 1918, pp. xvii–xxxvi, with a map.

FOR the subject of his presidential address to the Geological Society of South Africa Dr. du Toit chose the general characters and distribution of the rocks of the Karroo System. Sufficient work has now been accomplished to allow of a discussion of the correlation of the subdivisions of the system in different parts of the Union. An important conclusion has been reached in the establishment of a stratigraphical break between the Dwyka and Ecca Series, beginning somewhere between East London and Pondoland and increasing in importance towards the north-east; this accounts for certain anomalies seen in Natal and the Transvaal, where there is no equivalent of the Upper Dwyka shales of the Cape Province. Palæontological study now tends to show that the Dwyka Series is of Upper Carboniferous age, while the Ecca and Lower Beaufort Beds are Permian, the Upper Beaufort, Molteno, and Red Beds are Trias, while the uppermost volcanics may possibly be Rhætic. The author is to be congratulated on an excellent summary of a large subject.

R. H. R.

REPORTS AND PROCEEDINGS.

Geologists' Association.

1. *June* 7, 1918.—J. F. N. Green, B.A., F.G.S., President, in the Chair.

The following paper was read:—

"The Skiddaw Granite: a Structural Study." By J. Frederick N. Green, B.A., F.G.S.

The problem of the age of the Skiddaw Granite can only be attacked by structural methods. The distribution of cleavage in the aureole points to pressure later than the intrusion. The Mosedale fault, which brings unaltered parts of the Carrick Fell complex against garnet-cordierite-hornfelses of the inner aureole, is of the

type connected with the Devonian movements, and gives no indication of entering the Carboniferous. Microscopic examination of contact-altered rock suggests that the cleavage is later than the recrystallization. Thus the granite is older than the chief movements (Devonian). It is associated with an anticline demonstrably pre-Bala, running oblique to the Devonian folding, and is therefore probably itself pre-Bala and of the same age as the surrounding intrusions which belong to the Borrowdale suite.

The following lecture was delivered:—

"Diagrams illustrating the Significance of Rock Analyses." By John William Evans, D.Sc., LL.B., F.G.S.

The diagrams are of two kinds: (1) Individual rock diagrams intended to indicate at a glance the significance of the analyses of a rock or complex mineral silicate; (2) Linear rock diagrams. The different types of linear or variation diagrams, in which the chemical constituents of different rocks are represented by vertical distances, were reviewed and a new type proposed in which each rock is represented by two diagrams: (*a*) alumina diagram, (*b*) silica diagram.

In describing these diagrams, the lecturer discussed various problems connected with the genesis and composition of igneous rocks.

2. *July* 5, 1918.—J. F. N. Green, B.A., F.G.S., President, in the Chair.

The following lecture was delivered:—

"A Visit to Christmas Island and the Cocos-Keeling Islands." By C. W. Andrews, D.Sc., F.R.S., F.G.S.

The structure and physical geography of Christmas Island (Indian Ocean), a raised coral island, was described and compared with those of the Cocos-Keeling Islands, a typical atoll. Some account of the fauna and flora of Christmas Island was given, with special reference to the means of colonization of oceanic islands.

The lecture was illustrated by lantern slides.

CORRESPONDENCE.

THE PRE-THANETIAN EROSION OF THE CHALK.

Sir,—I should like to express to Mr. C. N. Bromehead my grateful thanks for his criticism of my paper on the Pre-Thanetian Erosion of the Chalk of the London Basin. I am afraid I must plead guilty to the charge of not having made use of all the evidence available, in ignorance as I was of the appearance of the Geological Survey Memoir on *The Geology of Windsor and Chertsey*. This memoir has, I suppose, been published since the outbreak of war and I have been continuously on active service, first flying in France and later serving afloat, since 1915. In any geological work with which I endeavour to beguile the tedium of life afloat I am greatly handicapped by being unable to make references to authorities, or even to consult earlier work of my own. The paper under present discussion was simply the outcome of an attempt on my part to apply cartographic methods to the data in my possession bearing upon the

question at issue. The results seemed to me interesting and worthy of print. Yet while being the first to admit the scantiness of my data, I cannot bring myself to agree with a policy which refrains from any kind of cartographical expression until ample data have accumulated. Comparative treatment and correlation of items of information in ways such as I have adopted, as well as being the strictly scientific method of procedure, is that which puts each item to its maximum of utility. I am convinced that field-geologists would often save themselves much haphazard wandering if they made greater use of cartographical methods beforehand. It is true that very limited data produce very generalized results, but the method works out its own salvation in the long run, and the results then achieved are unattainable in any other way. It is very faint praise to say that "when the amount of evidence available is larger, the method may be of some value". Had I been in the more fortunate position of Mr. Bromehead, I should long ago have given cartographical expression to my data. The result would have been a map full of imperfections, and doubtless in places at variance with field observations. Yet the steady incorporation of each fresh item of information would bring that map nearer and nearer to perfection and more and more in agreement with field observations.

Much as I should like to, I am unable, at the moment of writing, to discuss in any detail with Mr. Bromehead the other points which he raises. He remarks that "it seems natural to ascertain as far as possible the zone of the Chalk immediately underlying the Tertiary at the boundary of the latter, and to check the zones whose presence beneath the Tertiary is deduced from borings by these facts". I take it, then, that if Mr. Bromehead observed the *Marsupites* zone (say) immediately underlying the Tertiary at the boundary of the latter, he would naturally expect to find the same zone beneath the Tertiary cover. This seems to me a wilful ignoring of the teachings of tectonics, and since we already know that a strong unconformity exists between the Tertiaries and the Chalk, a most unsound view to take.

With regard to the "series of gentle folds whose axes run about E. 15° S.", referred to by Mr. Bromehead, I spent considerable time in 1913 studying these as well as evidences of disturbances of quite different relationship. A fact which made a profound impression upon me was that whereas in the Isle of Wight the Upper Chalk is 1,200 feet thick, in Dorset 1,000 feet, in Berks 800 feet, and in Norfolk 1,000 feet, yet in the London Basin, beneath the Tertiary cover, it is often less (and in places considerably less) than 300 feet. In view of this and many other facts, I concluded that while the evidence of a system of approximately east and west folds, including those referred to by Mr. Bromehead, was indisputable, yet this folding did not take the place of premier importance in determining the character of the denudation undergone by successive members of the Mesozoics, including the Chalk. The interesting items of field observation cited by Mr. Bromehead support his tentative suggestion of a set of approximately east and west folds in the Beaconsfield–Winkfield area, and it should be borne in mind that these

undulations must affect the level of the base of the Chalk, and in constructing my map showing levels in the base of the Chalk I was without adequate data concerning these anomalous levels in this particular area. With the incorporation of a sufficiency of data in the maps the final result would agree with field observations—and while the data accumulate a faulty map is better than no map.

H. A. Baker.

Afloat,
H.M.S. "Carysfort".
July 25, 1918.

NOTES AND QUERIES FROM NEW ZEALAND.

Sir,—I am forwarding two photographs in which perchance some of your readers may be interested. One represents the common rhombohedral multiple twin of calcite, seen on a weathered surface of the mineral, and the other an unknown fossil. [We omit the description of the photographs, which is appended to the figures given below.—Ed. Geol. Mag.]

I have discarded all thought of inorganic origin for the "fossil" on account of the great regularity and the successive layers shown, but can offer no convincing suggestion as to the actual nature, and shall be grateful for any information thereon.

John A. Bartrum (Lecturer in Geology).

University College,
Auckland, New Zealand.
May 6, 1918.

Having referred Mr. Bartrum's photographs to our colleagues Dr. G. F. H. Smith and Dr. F. A. Bather, of the British Museum (Natural History), Cromwell Road, we have been favoured with the following remarks thereon.—Ed. Geol. Mag.

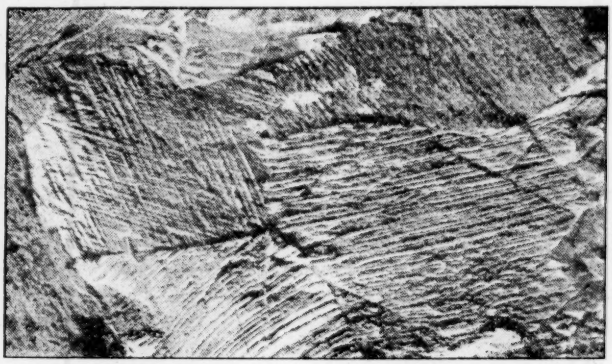


Fig. 1: Calcite Cleavage.—This shows clearly the crossing lamellæ seen on a weathered surface of a specimen of twinned calcite from Port Waikato, New Zealand. The lamellæ are usually rendered conspicuous owing to readier solution along the composition planes, but occasionally it appears as if there has been differential solution of the opposed sets of twin-lamellæ.—G. F. H. S.

Fig. 2: Crustacean Tracks in New Zealand Tertiaries.—This photograph, of natural size, depicts a portion of a large slab of soft sandstone recently exposed in strata of Middle Tertiary age along Beach Road, Auckland, New Zealand. The surface is covered with feather-like or fern-like markings which represent casts formed in the tracks left by some creature. The track (not the cast) consists of a median groove from which leaf-like imprints are given off on each side. The groove, which has a semicircular section, is about 5 mm. wide and pursues a gently sinuous course. Each appendage is about 13 mm. long, has a curved free margin, the curve having a radius of about 19 mm., and is overlapped by the corresponding margin of the adjacent imprint at a distance varying in different appendages from 3·5 to 6 mm. The greatest width in each case is at about two-thirds the distance from the point of origin. The axis of each appendage forms with the median axis of the whole imprint an angle varying between 35° and 75°, the greater angle usually being on the convex side of a sinuosity in the median track. It is hard to say whether the appendages are opposite or alternate.

Markings like those in Fig. 2 were formerly assigned to marine algæ (Chordophyceæ) or to annelids (*Nereites*), but the observations of many naturalists, summarized and supplemented in Nathorst's

classical memoir "Om spår af några evertebrerade djur, etc." (1881, K. Svenska Vet. Akad. Handl., vol. xviii, No. 7), have shown that they are almost certainly to be attributed to Crustacea. Such a track as the present one was probably formed by a large crustacean swimming close to the sea-floor rather than crawling on a mud-flat. It is of the same general character as *Polykampton alpinum* Ooster, 1869, from the Rhætic of Switzerland ("Protozoë Helvetica," vol. i, p. 23, pl. iv), and *Delesserites foliatus* R. Ludwig, 1869, from the Upper Devonian of Dillenburg (*Palæontographica*, vol. xvii, p. 113, pl. xx, fig. 4).—F. A. B.

OBITUARY.

E. A. NEWELL ARBER,
M.A., Sc.D., F.G.S., F.L.S.

BORN AUGUST 5, 1870. DIED JUNE 14, 1918.

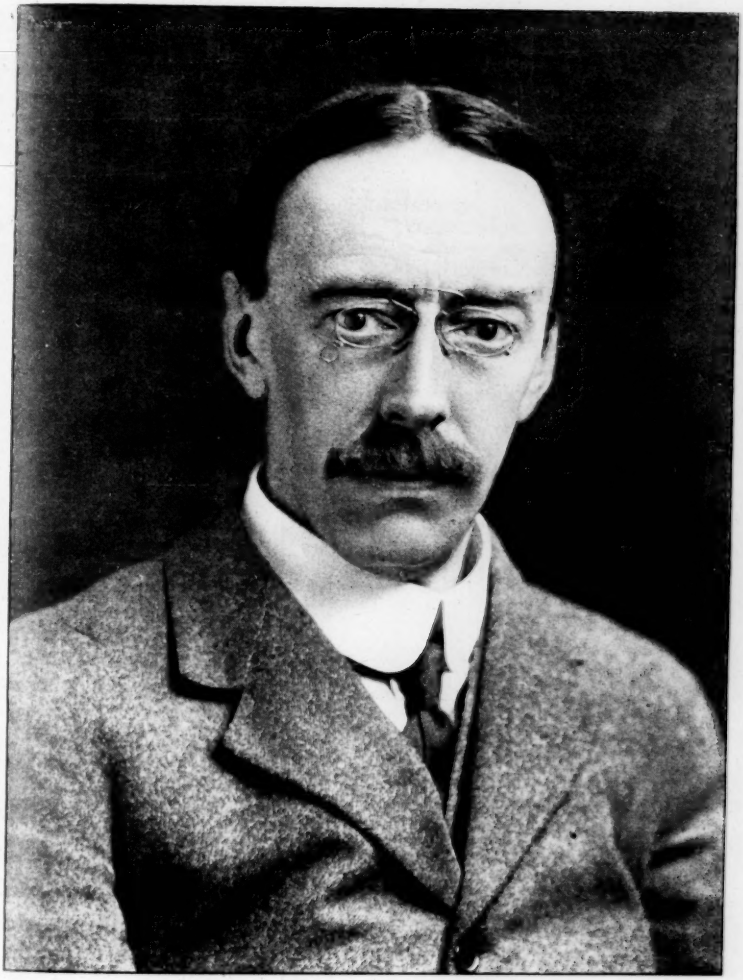
(WITH A PORTRAIT, PLATE XV.)

EDWARD ALEXANDER NEWELL ARBER was born at No. 5 Queen Square, Bloomsbury, in 1870. His father was Edward Arber, afterwards Professor of English at Mason's College, Birmingham, and known as the editor of many English classics. His mother (*née* Marion Murray), the daughter of a Glasgow publisher, was the niece of Dr. John Sutherland, an early authority on army sanitation, who was closely associated with Florence Nightingale's work in the Crimea.

Newell Arber had much illness in early boyhood, and at the age of fifteen he was sent, for the sake of his health, to Davos, where he spent more than a year. It was during his first Swiss summer that he awoke to the fascination of botany; his interest in geology was aroused later, apparently at the beginning of his Cambridge career. In 1895 he came up to Trinity College, and after an undergraduate period broken by ill-health, he took the two parts of the Natural Sciences Tripos in 1898 and 1899, specializing in Botany and Geology.

In 1899 Professor T. McKenny Hughes nominated Newell Arber to a Demonstratorship in Palæobotany in the Woodwardian (afterwards Sedgwick) Museum. This post, which he held for the rest of his life, involved the curating of the palæobotanical collections, as well as elementary and advanced lectures and demonstrations in fossil botany. Newell Arber threw himself enthusiastically into museum work, and during his tenure of the Demonstratorship about 5,000 plant fossils were added to the collections, almost entirely through his instrumentality. Between 1901 and 1906 he was also responsible—in the first year, under Dr. Henry Woodward, and after that, under his successor, Dr. Arthur Smith Woodward—for the naming and arrangement of the palæobotanical specimens in the Geological Department of the British Museum (Nat. Hist.). He consolidated his knowledge of fossil plants by repeated visits to most of the principal museums in Europe in which important collections are to be found.

Research flourished in Newell Arber's laboratory, where, in



Elliott & Fry, Photo. Bale, Sons and Danielsson, Ltd.

Yours sincerely

E. A. Newell Arber

addition to some sixty of his own memoirs, about twenty-five original papers were produced (either jointly or independently) by a group of students including at different times Bernard Smith, H. Hamshaw Thomas, L. J. Wills, W. T. Gordon, D. G. Lillie, R. D. Vernon, A. W. R. Don, R. H. Goode, and others. In 1905 a moiety of the Lyell Fund was awarded to Newell Arber by the Geological Society, and in 1914 he was elected an Honorary Member of the New Zealand Institute in recognition of his work on Australasian geology.

From the strictly geological standpoint, Newell Arber's contribution to the science may perhaps be summarized as consisting chiefly in the application of palæobotanical evidence to stratigraphical problems. One of his early memoirs (1903) dealt with the use of Carboniferous plants as zonal indices, a subject of which the foundations for this country had been so firmly laid by Dr. Kidston. Much of Newell Arber's later work was concerned with further developments on these lines, and he produced a series of papers dealing with the fossil floras and geological structure of the English coal-fields. His book on *The Natural History of Coal* was subsequently translated into Russian. The economic bearing of his palæobotanical work resulted in a consulting practice concerning the geology of coal both in this and other countries. Newell Arber did not confine his attention, however, to the Palæozoic period, but studied also the fossil floras of the Mesozoic rocks, especially those of the southern hemisphere. In this connexion his British Museum *Catalogue of the Glossopteris Flora* (1905) may be mentioned, and his recent account of the earlier Mesozoic Floras of New Zealand (1917). He continued his work to within less than three months of his death, leaving memoirs, in various stages of completion, relating to general palæobotany, and to Devonian, Carboniferous, and Mesozoic plants; it is hoped that some of these may eventually be published.

Newell Arber had an exceptionally wide knowledge of geological literature, which embraced even its obscurest corners. His interest in bibliographical questions and his high standard of accuracy in such matters, were somewhat unusual in a scientific man and were probably due to his father's influence. But he was no arm-chair geologist. He laid great stress on the importance of taking his research pupils into the open, where he initiated them into the methods of outdoor work. He had that instinct for the field, common to so many geologists, which on its material side results in a complete grasp of topography, and on its romantic side may rise to a capacity for being possessed by an absorbing passion for a tract of country. Botanically, Switzerland was his Mecca, while in his geological life Devonshire held a corresponding place. The desire to get there was often almost painfully intense; to quote from one of his letters—"I have had a bad attack of the 'West [Devon] a calling' . . . It gets worse and is getting beyond my control." Newell Arber made twelve geological expeditions to North Devon, mainly in connexion with his study of the Upper Carboniferous rocks. The difficulties of the work were extreme. As he wrote after the appearance in 1904 of his paper on the Culm Measures of

this part of England—"In the old days in the train I approached Bideford with great sinkings of heart. The possibilities of failure were immense and the chances of success seemed *nil*. Altogether I suppose it was the hardest nut I shall ever have to crack and I marvel at my luck." Later, as a by-product of this stratigraphical study, he was drawn to an investigation of the physical geology of North Devon, and in particular of the coastal waterfalls, which resulted in his book on the coast scenery of the region (1911). In much of this work D. G. Lillie and Inkermann Rogers were associated with him.

That deep-seated delight in field-work, which is in some ways the ultimate joy of the geologist, is indicated by a passage from one of Newell Arber's letters, which may perhaps not unfitly conclude this tentative outline of his geological life. "I thought I would take a holiday for the rest of the evening and indulge in a fit of 'field-fever' or 'field-dreams'. I wonder if you know what this is. Poor old Robert Dick heard or felt 'field-work' *calling* many a time. People who have been in the East, tell me they very often feel a great longing to return again. . . . A perfect day when one is in the field is one of the greatest things on earth. . . . My mania is quite a modest one. It is a desire to visit every spot in this country where fossil plants have ever been found. To gain that full power of knowledge which can only be got by having been to the place, seen it, photographed it and collected from it. When you have done this you have a 'grip' which is masterly."

A. A.

LIST OF THE MORE IMPORTANT GEOLOGICAL AND PALÆOBOTANICAL BOOKS AND MEMOIRS BY E. A. NEWELL ARBER. (A number of titles, including all purely botanical work, have been omitted for the sake of brevity.)

1901. "Notes on Royle's Types of Fossil Plants from India": GEOL. MAG., Dec. IV, Vol. VIII, pp. 546–9.

1902. "On the Clarke Collection of Fossil Plants from New South Wales": Quart. Journ. Geol. Soc., vol. lviii, pp. 1–26, 1 pl., 1 text-fig.

"Notes on the Binney Collection of Coal-Measure Plants. Part III: The Type Specimens of *Lyginodendron Oldhamium* (Binney)": Proc. Camb. Phil. Soc., vol. xi, pp. 281–5, 2 text-figs.

1903. "The Fossil Flora of the Cumberland Coalfield, and the Palæobotanical Evidence with regard to the Age of the Beds": Quart. Journ. Geol. Soc., vol. lix, pp. 1–22, 2 pls.

(Conjointly with A. C. SEWARD.) "Les Nipadites des Couches Éocènes de la Belgique": Mém. du Musée royal d'hist. nat. de Belgique, t. 2, 16 pp., 3 pls.

"Notes on some Fossil Plants collected by Mr. Molyneux in Rhodesia": Quart. Journ. Geol. Soc., vol. lix, pp. 288–90.

"On the Roots of *Medullosa anglica*": Ann. Bot., vol. xvii, pp. 425–33, 1 pl.

"The Use of Carboniferous Plants as Zonal Indices": Trans. Inst. Min. Eng., pp. 371–80.

"On Homœomorphy among Fossil Plants": GEOL. MAG., Dec. IV, Vol. X, pp. 385–8.

"Notes on Fossil Plants from the Ardwick Series of Manchester": Mem. and Proc. Manchester Lit. and Phil. Soc., vol. xlviii, Man. Mem., No. 2, 32 pp., 1 pl., 1 text-fig.

1904. "*Cupressinoxylon Hookeri*, sp. nov., a large Silicified Tree from Tasmania": GEOL. MAG., Dec. V, Vol. I, pp. 7–11, 1 pl., 2 text-figs.

1904. "The Fossil Flora of the Culm Measures of North-west Devon, and the Palæobotanical Evidence with Regard to the Age of the Beds": Phil. Trans. Roy. Soc. Lond., ser. B, vol. cxcvii, pp. 291–325, 2 pls.
(Conjointly with I. ROGERS.) "Note on a New Fossiliferous Limestone in the Upper Culm Measures of West Devon": GEOL. MAG., Dec. V, Vol. I, pp. 305–8.

1905. "On some New Species of *Lagenostoma*, a Type of Pteridospermous Seed from the Coal Measures": Proc. Roy. Soc., vol. lxxvi B, pp. 245–59, 2 pls.
"On the Sporangium-like Organs of *Glossopteris Browniana*, Brongn.": Quart. Journ. Geol. Soc., vol. lxi, pp. 324–38, 2 pls.
Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Nat. Hist.). Being a Monograph of the Permo-Carboniferous Flora of India and the Southern Hemisphere. London, lxxiv + 255 pp., 8 pls., 1 map, 51 text-figs.

1906. "On the Past History of the Ferns": Ann. Bot., vol. xx, pp. 215–32, 1 text-fig.
"Bibliography of Literature on Palæozoic Fossil Plants, including some of the more important memoirs published between 1870–1905." Progressus Rei Botanicæ. Bd. i, pp. 218–42.
"The Origin of Gymnosperms": Science Progress, vol. i, No. 2, pp. 222–37.

1907. "On the Upper Carboniferous Rocks of West Devon and North Cornwall": Quart. Journ. Geol. Soc., vol. lxiii, pp. 1–27, 3 text-figs.
"A Note on Fossil Plants from the Carboniferous Limestone of Chepstow": GEOL. MAG., Dec. V, Vol. IV, pp. 4–5.
(Conjointly with JOHN PARKIN.) "On the Origin of Angiosperms": Linn. Soc. Journ. Bot., vol. xxxviii, pp. 29–80, 4 text-figs. (Translated into German as "Der Ursprung der Angiospermen": Österreich. bot. Zeitschr. Jahrg., 1908, p. 89, etc.)
"On Triassic Species of the Genera *Zamites* and *Pterophyllum*: Types of Fronds belonging to the Cycadophyta": Trans. Linn. Soc. Lond., ser. II, Bot., vol. vii, pt. vii, pp. 109–27, 3 pls.

1908. "On a New Pteridosperm possessing the Sphenopteris Type of Foliage": Ann. Bot., vol. xxii, pp. 57–62, 1 pl.
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VLADIMIR PROCHOROVITCH AMALITSKY.

BORN 1860. DIED DECEMBER 28, 1917.

WE regret to learn that Professor Amalitsky, of Warsaw, died suddenly from heart failure last December at Kislovodsk, North Caucasus. He was born in Volhynia in 1860, and received his scientific education at the University of Petrograd, where he was especially attracted to geology by Professor Inostransev. He soon became an accomplished student, and early in his career was appointed Professor of Geology in the University of Warsaw. Afterwards he assumed the direction of the Polytechnic Institute in Warsaw, and was occupied with his duties there at the outbreak of war in 1914.

Professor Amalitsky devoted himself with great success to the study of the Permian formations of Russia, and made a special effort to discover remains of terrestrial and freshwater faunas and floras in these rocks. He first met with unusually well-preserved freshwater bivalved shells of the family Anthracosiidæ, which he described in the *Palæontographica*, vol. xxxix (1892), and in the first part of a Russian work intended to treat all aspects of Permian geology, published in Warsaw, also in 1892. Three years later he visited the British Museum, with his equally accomplished wife, who always shared his labours, and there he compared his Russian fossils with the corresponding shells from the Karoo formation of South Africa. The results of his researches were contributed to the Geological Society of London in a paper entitled "A Comparison of the Permian Freshwater Lamellibranchiata from Russia with those from the Karoo System of South Africa" (Quart. Journ. Geol. Soc., vol. li, pp. 337–51, pls. xii, xiii, 1895).

While in London, Professor and Mrs. Amalitsky also studied the Karoo reptiles and other Permian and Triassic fossils. They then spent four seasons in exploring promising localities in the Permian region of the northern Dwina, and discovered not only more freshwater shells but also the characteristic *Glossopteris* Flora and great deposits of concretions containing the skeletons of Reptiles and Labyrinthodonts. In 1899 and 1900, with the aid of funds from the Russian Ministry of Public Instruction, they made extensive diggings in the beds of bone-bearing concretions and obtained a very large collection which was sent to the University of Warsaw. Skeletons of Pariasaurians proved to be especially abundant, and there were numerous remains of Dicynodonts, Theriodonts, and Deuterosaurians, besides well-preserved Labyrinthodonts. In December, 1899, Professor Amalitsky made a general report on his first year's official work to the Imperial Society of Naturalists of Petrograd, and published this as a separate pamphlet at Warsaw in